Received 23 December 2012
Revised 15 June 2013
27 September 2013
Accepted 4 October 2013

The impact of operations and maintenance practices on power plant performance

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Abstract

Purpose – The purpose of this paper is to examine the impact of operations and maintenance (O&M) practices, individually and collectively, on power plant performance.

Design/methodology/approach – Data were collected from more than 100 power plants in Australia and Malaysia. The reliability and validity (content, construct, and criterion) of the practice and performance measures were evaluated.

Findings – Committed leadership and maintenance-oriented practices as part of a total productive maintenance (TPM) philosophy were found to be the main differentiators between high and low performing plants.

Research limitations/implications – The research is cross-sectional in nature, therefore, it does not permit us to account for the lag between implementation and performance. Second, the performance measures are subjective and may be subject to response bias.

Practical implications – The implication of the research findings for plant managers is that they need to allocate more "softer" resources to the O&M function if they expect high plant availability.

Social implications – Apart from capacity and fuel cost, operating costs are an important source of differentiation for power plants. The implication is that reduction in operating costs is directly related to the reduction of consumer power bills.

Originality/value – The reader will learn from this paper that committed leadership and maintenance-oriented practices have greater explanatory power in the regression models than employee involvement, customer focus, strategic planning, and knowledge management. This knowledge is important because it emphasises that in addition to quality management practices, which are focussed on the development of the people aspects of the organization, the plant equipment and physical assets should also be given equal emphasis, in order to improve operational performance of power plants.

Keywords TQM, Quality management, TPM, Operations, Maintenance, Plant performance

Paper type Research paper

Introduction

The purpose of the restructuring of the electricity supply industry (ESI) was to increase delivery efficiency through market competition (Electricity Supply Association of Australia Limited, 2001; Loredo and Suarez, 2000; Yokell and Violette, 1988). Restructuring has introduced new risks for power plant operators. At the operation level, cost, plant reliability and availability, safety, and environmental compliance are important priorities (Draper Jr, 1998; Matusheski, 2000). Plant reliability and availability underpin power plant business performance. Failure of plants to attain high levels of availability can result in significant financial risks to the plant operators. For example, a study conducted on one of the thermal power plants in Malaysia found that it had cost its parent company losses amounting to RM175m (AUD$58 m) in lost

Journal of Manufacturing Technology Management
Vol. 25 No. 8, 2014
pp. 1148-1173
© Emerald Group Publishing Limited
1741-038X
DOI 10.1108/JMTM-12-2012-0122

availability over a period of 2.5 years. It was determined that these losses were a result of poor plant availability. To achieve this objective, relevant plant level operations and maintenance (O&M) activities should intensify to ensure high plant availability and utilization levels are achieved (Davis, 1995; Desirey, 2000; Moubray, 1997; Swanson, 2001; Tsuchiya, 1992).

However, researchers and industry practitioners have often overlooked the effects of equipment availability on operational performance (Fredendall *et al.*, 1997; Nakajima, 1989; Schonberger, 1986). Roth and Miller (1992) asserted that maintenance management might well be the biggest challenge facing power plants in a fiercely competitive market. In order to sustain high plant availability and at the same time meet the cost and regulatory requirements, we contend that appropriate maintenance strategies need to be integrated with other organizational management functions (Nakajima, 1989;David, 1993; Lindsay and Peter, 1998).

Contributing to the gaps in knowledge that exist on power plant availability can assist researchers and practitioners in understanding the role of operations management practices in determining power plant performance in order to be competitive in a deregulated environment. Consequent to the above, we have articulated the research question:

RQ1. Which O&M practices are critical predictors of plant performance?

Answers to the research question would provide a deeper understanding of best predictors of plant performance. This would assist managers to allocate limited resources to those areas, which have the most significant contribution to plant performance.

Literature review

We reviewed the literature on total quality management (TQM) and total productive maintenance (TPM) to identify the key variables that should be included in the theoretical framework. The studies that we draw upon for this work were carried out in the past decade. The relationship between TQM practices and organizational performance has been explored in many empirical studies (Ahire *et al.*, 1996; Black and Porter, 1996; Flynn *et al.*, 1994; Powell, 1995). Samson and Terziovski (1999) investigated the relationship using the Malcolm Baldrige National Quality Award (MBNQA) criteria in a large cross-sectional examination of over 1,000 manufacturing companies in Australia and New Zealand.

The study found that the seven constructs in the MBNQA criteria were valid and reliable measures of the TQM concept. This finding is consistent with the conclusion in a study by Ahire *et al.* (1996) who found that product quality is strongly linked with human resource management, and Powell (1995), who found that competitive advantage is more strongly related to human factors such as executive commitment, open organization, and employee empowerment and less dependable on the techniques and tools of TQM. Other researchers and practitioners have come to realize the importance of maintenance strategy to increase the availability of existing equipment and reduce the need for additional capital investment.

Most of the studies in this area involve the study of the impact of TPM and its implementation on manufacturing performance (Bamber *et al.*, 1999; Brah and Chong, 2004; Chan *et al.*, 2005; Cooke, 2000; Ireland and Dale, 2001; McKone and Weiss, 1998a). Some of these studies, were found to have little or no effect on performance (see Cigolini and Turco, 1997), or that the efficacy of the TPM program has to be implemented together with other quality improvement programs like TQM and JIT (McKone *et al.*, 2001). These studies anecdotally claim that an integrated framework incorporating elements from TQM and TPM can assure successful implementation of O&M strategy and better plant performance.

We limit the operationalization of the TPM construct to maintenance practices such as prevention maintenance, record keeping, reliability centered maintenance and so on. Other empirical research has also been carried out where the studies consider more than one of the three concepts TQM, JIT, and TPM. There is a general agreement in the literature (McKone *et al.*, 1999) that TQM, JIT, and TPM constitute quality programs for performance improvement and are closely interlinked with each other. For example, practices such as committed leadership, customer focus, use of information, and strategic planning are common to TQM and JIT and to some extent, TPM.

We argue that the practices identified as comprising TQM, JIT, and TPM can generally be subdivided into "soft" or people-oriented practices and "hard" or technical-oriented practices. In our study, we measure both "soft" and "hard" practices together and relate them to plant performance. On the performance construct, we incorporate both operational as well as social/regulatory outcomes.

We define "soft" practices as related to leadership, employees, as well as customers. "Hard" practices, on the other hand, concern the techniques, tools, and processes in the organizations, which comprise infrastructure components such as planning, use of information, and maintenance functions. Therefore soft practices are those practices that can lead to the development of an organizational culture to facilitate high performance. Hard factors are associated with processes, tools and techniques used by an organization to attain its objectives.

Theoretical framework and hypothesis

We draw from the TQM literature in order to ascertain which factors we should include in the O&M framework. These factors are: committed leadership, employee involvement, customer focus, strategic planning, knowledge management, and TPM-orientation. Committed leadership, employee involvement and customer focus all involve the need for people relationships, and therefore are categorized under the people-oriented soft category.

Conversely, the O&M factors of strategic planning, knowledge management, and TPM-orientation maintenance are more likely to be "mechanistic" or process-based and therefore categorized under the technically oriented hard category (Tse *et al.*, 2007). Our empirical work aims to validate these factors and determine the relationships between these factors and plant performance. Figure 1 shows the O&M Practice framework.

Definitions

This section defines the constructs that have been included in the O&M Practice framework (Figure 1).

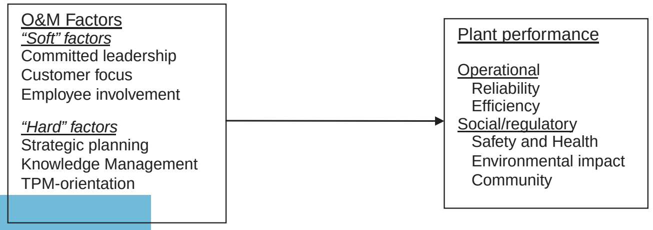

Figure 1.
Theoretical framework

Committed leadership

This factor is considered as one of the key "drivers" of performance. It examines senior leadership involvement in setting direction for their power plants and creates a culture focussing on customers' requirements (Malcolm Baldrige National Award Criteria, 1994). Leadership also plays a key role in facilitating innovative changes in the power plant work environment; to create a safe and conducive work-place; install a management system supporting the plant's purpose of high performance (Skinner, 2004) through continual learning, employee development, and close sensitivity to the local community and natural environment. In our study, the leadership practices relate to the transformational leadership style (Bass, 1985). Therefore, committed leadership is expected to have a significant and positive relationship with plant performance.

Employee involvement

In our study, we have included employee involvement, as literature on quality and TPM suggests that the participation and commitment of employees bring about improvement in performance (Davis, 1995; Dean and Bowen, 1994; Nakajima, 1988; Tsuchiya, 1992). Literature on quality suggests that the participation and commitment of all employees are "enabled" to bring about improvement in performance, giving credence to the fact that organizations' greatest assets are in their workforce and the people making up the organizations (Huselid, 1995; Youndt *et al.*, 1996). By enabling them through cross-functional training, empowerment, skills development, use of cross-functional teams, and others, their creativity in solving problems and contribution to the achievement of quality as well as plant efficiency can be considered as sources of competitive advantage (Barney, 1991).

Based on the above discussion, a higher level of employee involvement can bring about a greater level of quality and enduring solutions to plant problems. In this way, plant productivity is enhanced and improved. In addition, higher levels of employee involvement create better understanding and a climate of trust in the organization. The construct employee involvement is therefore predicted to have a positive and significant effect on plant performance. Our survey for this factor focusses on such issues as elimination of barriers, evaluation of employee suggestions, empowerment of staff, cross-functional teamwork, and increased autonomy in decision making.

Customer focus

The TQM literature asserts that meeting customers' needs is the main purpose of the existence of the organization (Deming, 1982; Imai, 1986; Juran, 1992). It considers the relationship the organization establishes that leads to customer satisfaction, loyalty, and retention (Drucker, 1975) and how the plant manages the customer relationship and communication of the concept of customer to the workforce. The above indicates that the customer focus construct is a key factor in plant performance and is therefore expected to have a positive and significant relationship with plant performance. Measures relating to the customer focus construct include knowing external customers requirements and expectations, customer satisfaction, prompt resolution of customers complaints and problems, and actively and responsive to customers' needs.

Strategic planning

This factor describes the plant's strategic and business planning as well as deployment of plans (Davis, 1995; Evans, 1996). It emphasizes the long range planning, alignment of operational resources with corporate business mission, a process for formal strategic planning, and the extent of the centrality of purpose and mission of the plant within. With respect to power plants, strategic planning provides the link between the present and the future. It also promotes a clear understanding among management and employees of the plant's link to its corporate mission, vision and business strategies, resulting in an alignment of resources internally to attain plant objectives (Ansoff, 1987). Thus, it is expected that this construct will have a positive and significant relationship with plant performance.

Knowledge management

The TQM literature suggests that information and data is the "lifeblood" of the organization (Skinner, 2004), and organizations that collect and analyze information consistently tend to be successful. This factor is concerned with the underlying TQM philosophy that decision making should be based on facts (Crosby, 1979; Deming, 1982; Feigenbaum, 1991). It involves collection and analysis of data and information about customer needs, operational performance and problems, and feedback on improvement activities or strategies undertaken by the plant, and knowledge of the complexity of the plant operations.

TPM-orientation

This factor is concerned with activities that are responsible for equipment effectiveness. TPM (Swanson, 2001) focusses on the maintenance strategy, the extent of preventive maintenance, the use of root cause analysis for identifying defects and carrying out trouble-shooting activities to bring the plant back to normal operation in the shortest time possible, and keeping and use of records for maintenance analysis as well as carrying out reliability-based maintenance activity. High production is assured which in turn motivates plant management to commit more resources such as training and skills development to sustain the TPM program (Senju, 1992). Employees too are motivated to be more involved. Teamwork increases which promotes greater shared responsibility and more ownership of plant problems (Zainal and Noorliza, 2000). Plant performance increases overall when equipment is better and effectively maintained. Therefore, the TPM-orientation construct is likely to be positively and significantly related to plant performance.

Plant performance

Plant performance is measured along dimensions of operational (reliability, capacity utilization) and social/regulatory (environment, community, safety). We have decided to use plant availability, which is an outcome of plant reliability as an indicator for the continual operation and viability of the power plant. All the above performance constructs are measured subjectively. Though many researchers argue for a balanced set of financial and non-financial measures to measure performance, there are a number of reasons to opt for subjective operational and social/regulatory data in this study (Kaplan and Norton, 2004). The main reason for the use of subjective non-financial measures to measure performance was the unwillingness of the deregulated power generation industry players to divulge "sensitive" commercial and financial information[1]. This is especially so with the privately held power companies which comprise a substantial portion of the sample size.

Hypotheses

This study tests the relationships between the soft factors such as committed leadership, customer focus, and employee involvement with plant operational as well as social/regulatory performance. Based on the foregoing, our hypotheses examine the relationships and predictive power of both the "soft" and "hard" factors with plant performance. The two hypotheses are:

H1. There is a significant and positive relationship between the people-oriented "soft" factors and overall plant performance.

H2. There is a significant and positive relationship between the technically or process-oriented "hard" factors and overall plant performance.

Testing the above hypothesized relationships on the three people-oriented soft factors are important because they provide useful information of their significance in relation to plant performance. In addition, they provide important information on the relative strengths of the three people-related constructs which can be used for comparison with the results of other studies that indicate people-related factors are important sources of competitive advantage (Powell, 1995; Samson and Terziovski, 1999). Similarly, testing of the hypothesized relationships on technically oriented hard constructs provide important information on the effect of technically-oriented O&M factors on plant performance.

Contextual factors

In order to control for systematic bias, a number of contextual variables are identified and included in this study, in order to examine whether these contextual variables affect the hypothesized relationships between the O&M model and plant performance. Such variables that are deemed important are plant size (number of employees) (Ketokivi and Schroeder, 2004), plant age (Joskow and Schmalensee, 1987), market environment (Ketokivi and Schroeder, 2004), and generation technologies (Woodward, 1958).

The plant organization size is classified into three categories: small, from one to 19 people, medium, from 20 to 100 people, and large, with more than 100 people. For plant age, we divided the power plants in two groups where one group consisted of those plants with <20 years of operation. The other group consisted of plants that had been in operation for more than 20 years. The 20th-year period is chosen to demarcate them into new and older plants, and is also the time period for most power purchase agreements, most notably power plants using gas turbine technology. As for market environment, we classified this factor into two classes, that is, regulated and open market. For generation technology, we classified them into the four dominant technologies of conventional thermal, simple cycle gas turbine, combined cycle gas turbine/steam turbine and hydro.

Methodology and data analysis

A mail survey was used to gather data from the power plants located in Malaysia and Australia in order to test the above hypotheses. Power plants in Malaysia and Australia were chosen for study because the restructuring and deregulation of the ESIs in the two countries started at the same time and this would provide a basis for comparison between the two countries. The names and mailing addresses of the power plants in Malaysia and Australia were initially gathered from the lists which appeared in the statistics section of the Energy Commission web site (Electricity Supply Department Energy Commission, 2004) and Electricity Supply Association Australia, respectively.

Sample population and response rates

The initial lists identified 63 and 206 plants in Malaysia and Australia respectively. The lists were scrutinized and adjustments made to include only those power plants that were operated commercially and subjected to some sort of competitive forces. Plants that were left off included those that were yet to be operational, those that operated singly to provide partial supply to isolated communities, those that were unmanned and remotely operated, experimental plants like solar powered generators, and in-house co-generators.

Our sample population includes "true" power generators that utilize conventional energy conversion technology. Such plants comprise conventional thermal steam plant, combine-cycle power plants, simple cycle gas turbines, reciprocating engines, renewable energy plants (e.g. wind farms), and hydro. The final list produced 42 and 173 individual power plants in Malaysia and Australia, respectively.

Mail out of the survey instrument was staggered in two phases. For the first phase, the survey questionnaire was sent to power plants within Malaysia in August 2006. In the second phase, the same survey questionnaire was mailed out to Australian power plants in October 2006. Responses from the two countries were collected over a period of two months each. A total of 108 responses were received, 41 from Malaysia and 67 in Australia. This yielded response rates of 98 and 39 percent, respectively, giving a total combined response rate of 50 percent. As will be explained and discussed in the data preparation section, these 108 responses formed the data set for all analyses in this study. Managers/team leaders in charge of the plant generating assets or plant operation answered all responses. The respondents were considered to have the necessary experience and knowledge on power plants operations.

Survey instrument

A total of 89 questions were included in an eight page long questionnaire. Development of the questions in the survey instrument was carried out by the researchers using a number of sources based on relevant literature in TQM (Ahire *et al.*, 1996; Black and Porter, 1996; Cua *et al.*, 2001; Powell, 1995; Samson and Terziovski, 1999), TPM (Brah and Chong, 2004; Desirey, 2000; McKone *et al.*, 1999; McKone and Weiss, 1998b) and maintenance (Desirey, 2000). Questions were formulated based on criteria that included The Australian Business Excellence Framework (2004), Malcolm Baldrige National Quality Program Criteria for Performance Excellence (2007) and Tenaga Nasional Berhad (2006). The questionnaire was pre-tested with colleagues and power plant managers in Tenaga Nasional Berhad, Malaysia as well as power plant engineering and management consultants. Changes were made to the questionnaire based on the pre-test feedback.

There were 59 research questions out of 89 originally selected that were relevant to the research questions associated with this study. These 59 questions were the variables used as inputs for analysis. These variables were assigned to seven constructs as theorized in the O&M Model: committed leadership, customer focus, employee involvement, strategic planning, knowledge management, TPM-orientation, and performance.

Descriptive statistics

Basic data and information were also sought from our respondents and the plants to profile them. The power plant profiles were described in terms of major process technology, location, plant age, number of employees, installed capacity sizes, products and services offered, competitive advantages, ownership, and availability and capacity utilization.

Response rate

A total of 215 questionnaires were sent out and 108 responses were received from power plants in both Malaysia and Australia. This worked out to a 50 percent response rate. The majority of the respondents were from the plant managers or staff who were in senior management positions at the power plants. Plants that did not have management positions responded through their officers-in-charge. About 92 percent of the respondents were plant managers and managers who hold senior positions in the power plants. Many of these managers have years of experience in the power generation industry. Besides being knowledgeable in the technical aspects of running a power plant, they are also involved in managing resources to ensure the viability of the business itself.

An analysis of the power plant work experience among the respondents shows that the average work experience was about 22 years. About 80 percent of the respondents had ten or more years working in the power generation industry. The highest work experience recorded in the sample data was 45 years. The majority of the respondents, nearly 40 percent, had between 20 and 30 years work experience in the power generation industry. Thus the survey questionnaire data used for the statistical analysis were the expressed opinions of experienced representatives from the power generation industry in Malaysia and Australia.

Plant organization size

Following the convention used in most management studies, plant size is classified according to the number of employees. The number of employees is used as a measure of organization size (plant size) in preference to financial figures. The power generation industry is very reluctant about giving out information on commercial performance; hence this study had taken into account the advice of seeking non-commercial data only from the respondents. In addition, the different power plants in the sample data have different accounting, tax and depreciation policies that would have resulted in an incompatible platform on which to base their performance.

Plant size (total installed capacity)

The majority of the power plants in the sample size are sized from ten megawatts and above. For the sample data in this study, only three power plants were found to have installed capacity of ten megawatts and less. A check reveals that the three are renewable energy power plants (landfill gas and mini hydro). Large power plants with installed capacities >100 megawatts tend to have more employees (that is, medium to large). However, the indication is that plants with higher installed capacities do not necessary indicate more employees working there. The power generation industry is highly automated, more so in modern plants constructed in the last few years. With more competition and privatization, the industry had undergone a change in terms of scale of employment with more emphasis on economic rather than social benefits. The sample data appears to have elicited a good spread of respondents in terms of organization size where the number of power plants is more or less equal in numbers for small, medium and large size categories.

Plant age

Most of the power plants in the sample data were relatively new, about 42 percent were less than 15 years old. About one-quarter had been in operation for more than 30 years. Therefore, it is not unreasonable to say that the sample data contains information on power plants with a relatively wide range of operating ages. In the later section of this thesis, power plants were divided in two groups where one group consisted of those plants with <20 years of operation, and the other group that had been in operation for more than 20 years. The 20th-year period is chosen to demarcate them into new and older plants, and is also the time period for most power purchase agreements, most notably power plants using gas turbine technology.

Location (market environment)

The power generation industries in both Malaysia and Australia have been opened up to competition, as represented by degree of regulation. Competition in the form of PPA-driven privatization, and thus limited in scope, is found in Malaysia and in the Australian States of Western Australia and Northern Territory. Open competition in the form of market bidding is prevalent in the states of Queensland, New South Wales, Victoria, South Australia and Tasmania. The sample data comprise responses of power plants located in the above-mentioned regions. The number of power plants in open market and PPA-driven privatized market regions was found to be nearly equal in the sample data.

Generation technology

We can classify the generation technologies based on the conversion processes from different energy sources into electrical energy. For this study, they are classified into conventional thermal steam turbine (ST) power plant, simple cycle gas turbine (GT) power plant, combined cycle GT/ST power plant, hydro, wind, and renewables. The four major generation technologies constituted more than 80 percent of the sample size. These four technologies are the dominant types of generation technologies used by the contemporary power industry.

These four dominant technologies of conventional thermal, simple cycle gas turbine, combined cycle GT/ST and hydro are more or less equally represented in numbers in the sample data. Wind and renewables constituted about two percent of the sample size. Though these two technologies are emerging in importance with the growing awareness of global warming, they are still at the infancy stage. Thus it is reasonable to suggest that the sample data represents a balanced mix of the generation technologies normally found in the power generation industry. In addition, the type of generation technology used is dependent on the availability of fuel resources in the country. Malaysia's generation mix is skewed toward the use of its indigenous gas resources. Australia's plentiful and easily accessible coal reserves in the eastern states of the continent shape its generation mix.

Thus we have, in Malaysia the predominant combined cycle gas turbine technology, which prevails to capitalize on the gas while the Australia relies very much on the well-proven technology of coal-fired steam turbine technology. Information regarding the prevalence of generation technologies and generation mix is discernible from the sample data. The pattern confirms the generation mix in both countries. The sample data is representative of the generation industry in the two countries in this aspect.

Products and services

The respondents were requested to list the electricity-related products or services offered by their power plants. The main energy products are base-load energy, intermediate-load energy, and peak-load energy. Ancillary services are also offered. These services are to maintain key technical characteristics of the network system.

They include services such as spinning or operating reserve (FCAS)[2], voltage support (NCAS)[3], and black-start[4] capability. That number of power plants in sample data that are classified into the various energy products and ancillary services. About 40 percent of the power plants concerned are peakers. The remainder is made up of base and intermediate load plants. This is a fair balance of generating assets in any system where peakers and non-peakers are needed to support a system economically and effectively. However, ancillary services in terms of FCAS, NCAS and black-start capability can be supplied by most power plants. These services are as a result of the design and operating philosophies that are incorporated into the power plant during the project development stage. More than 30 percent the surveyed plants offered FCAS and NCAS.

Base-load and intermediate-load demands are supplied by large conventional thermal and combined cycle power plants where economy of scale in the production of electricity is imperative. Hydro and simple cycle GT power plants fill the slot for peak demand. Characteristics such as quick response in start up and load following inherent in both hydro and simple cycle GT generators fit in nicely with the load demand volatility. Renewable, of course, caters to the base load demand for maximum efficiency. The sample data therefore represents a true cross-section of power plants in terms of load demand types. It also presents a picture that is representative of the types of plants in terms of generation technology in line with conventional power generation industry wisdom.

Ownership

Ownership is defined for this research as state or private. State-ownership here encompasses ownership by utility companies and public, whereas private ownership includes internationally based companies as well. Mixed ownership is the other category and is classified as other.

Competitive advantage

Literature and conventional wisdom in the power generation industry list that the main competitive advantages of power plants are based on their physical attributes. These physical attributes are unit size, number of operating units, low cost of plant maintenance, availability of spares, and last but not least, low or negligible fuel cost (Stoft, 2002). For this research, power plants respondents were requested to list the advantage of each of the physical attributes mentioned above as compared to their nearest competitors. Among the attributes, number of generating units stand out as an important contributing factor in plant competitiveness within the same category.

Though cost of fuel constitutes about 70 percent of the total generating cost in a conventional power plant (Bureau of Industry Economics, 1992), and thus its impact on any power plant competitiveness is high, the data here suggest that plants in the same category of competition use the same type of fuel. Hence, any competitive advantage in fuel cost is negated. For example, the Victorian power plants use readily available brown coal obtained from the same region. In Malaysia, however, the dominant fuel is natural gas that is supplied by the only national gas supplier at a fixed price.

Plant availability and capacity utilization

Last but not least, the survey also requested data on plant performance in terms of plant availability and capacity utilization. As this research also looks into the effects of competition on plant performance in these two measures, the data on power plant from Malaysia and Australia are compared. Deregulation in the power generation industry has stopped at privatization for Malaysia whereas Australia under its National Electricity Market (NEM) has an open wholesale market. The findings show that on both scores, there were more power plants in Australia with very high plant availability and capacity factors (for both cases, more than 95 percent). High plant availability means that the generating units are always ready to generate. However, power plants in the two countries have an almost similar number of power plants in the high category (more than 91 percent for plant availability) comprising about 66 percent of Malaysian and 69 percent of Australian plants. This indicates that market competition, to certain extent, may have some influence on plant performance in terms of plant availability.

There are, however, a noticeable number of power plants in Australia in this sample data with a capacity factor <10 percent. This indicates that there is a higher incidence of underutilized generating assets in Australia. The present industry structure in the NEM region is such that the portfolio balance of base, intermediate and peaking plants was overweight in base and intermediate sectors. Simhauser (2007), CEO of one of the largest power companies in Australia, pointed out that in his paper presented to an energy conference held in Australia on supply-side portfolio that peaking plants in NEM regions are "drifting further and further away from optimality." It means that there has been a build-up of a number of large conventional base-load steam plants that are modern and more efficient than older plants. As a result, existing but less efficient old thermal plants are pressed to operate in the peaking sector. For example, Queensland has a number of old coal-fired steam plants that on average are operated only during the summer months when demand is high.

Descriptive statistics

This section has reviewed the survey findings using descriptive statistics where the profiles of the participating power plants were investigated. Supplementary analysis on the competitiveness in terms of the physical attributes and comparison of operational performance of power plants in different market environments was made. The sample data reveal a cross-section of power generating plants in terms of types of plant size according to number of employees and installed capacities, plant age, generation technologies, ownership, plant location, and products/services offered. Respondents, the majority of whom were in senior management positions, were experienced in power plant operation and management. Thus the information provided was a reflection of their practices in a generally technically complex industry and can be accepted with high confidence.

The electricity industry is very much dependent on the type of natural fuel resources that a country has Malaysia, which espouses a four-fuel strategy based on coal, natural gas, oil and hydro, is at present very much dependent on natural gas (Electricity Supply Department Energy Commission, 2004) which is more efficiently utilized in the production of electricity from combined cycle gas turbines – hence the prevalence of this type of generation technology in that country. Conversely, Australia, which is blessed with an abundance of easily accessible and cheap coal deposits, uses coal as the main source of fuel in most of its power plants for electricity production. Other types of fuel used in the generation industry in both countries include hydro and to a certain extent, renewables. The kind of strategic resources in a particular country are reflected in the types of generation used, which are thus represented very well in the sample data.

Generation technology, location, plant age, and plant size are contextual variables used in the statistical analysis. Location here assumes the role of the competitive environment that is represented by the type of markets, that is, the Malaysian PPA-driven market and Australian open market. Plant age is categorized into two groups. Plant size in terms of the number of employees indicates a close pattern to plant size in terms of installed capacity. In line with extant research, the number of employees is used to represent plant size in this study (Ketokivi and Schroeder, 2004). Three categories, that is, small, medium and large, are employed for this purpose.

Assessment of non-response bias

In this study, the technique of wave analysis was used to assess non-response bias (Rogelberg and Stanton, 2007). This approach compares the survey variables of pre-deadline responses with late responders. As suggested, though, by Rogelberg and Stanton (2007) that this method does not indicate conclusively an absence of bias. Nevertheless, if a difference exists between the two groups, then some degree of non-response bias exists.

The data set of power plants from Australia was divided into two groups: pre-deadline and post-deadline. A total of 36 power plants made up the pre-deadline group. In total, 30 late respondents made up the post deadline group. A number of questions were identified from the survey questionnaire that had high predictive validity and tested for differences between the two groups (independent sample t-test) (Field, 2005). The results of the analysis indicate that there was no significant response bias in the sample concerned.

Incomplete responses

The second stage in the treatment of data was the issue of incomplete responses or missing responses. There were three missing data points in the relevant data set. SPSS missing value analysis was used to examine and test for significance of missing data distribution (Tabachnick and Fidell, 2007). The analysis indicated that the number of missing data in any one variable did not exceed 5 percent of data missing, and the distribution pattern of missing data was random. Thus, it could be inferred that the three missing data were missing completely at random.

Treatment of missing data includes removing cases or variables with missing data from the analysis, and using an imputation technique (Hair *et al.*, 1998; Tabachnick and Fidell, 2007). For this study, prior knowledge substitution was used. Tabachnick and Fidell (2007) suggest that this is an effective method when sample size is large and the number of missing values small. It basically involved imputing the missing data with a well-educated guess. This was carried out by identifying and observing the cases (i.e. power plants) with missing data variables and comparing these variables in other similar power plants, which had complete set of data.

Scanning for outliers

The third stage of data preparation involved the screening of outliers. This stage also included checking for data normality. Presence of outliers and normality of data usually exist together. All variables in the data set used the seven-point Likert-type interval scale. After appropriate treatment which includes variable transformation (Hair *et al.*, 1998; Tabachnick and Fidell, 2007) and deletions, skew was still present in 18 of the variables. The skew ranged from 1.00 to 1.90. These variables were retained (Hair *et al.*, 1998). Three other variables were heavily skewed (z-skew $= -3.787$, -4.319 and -4.541) and were removed from further analysis.

Analysis procedures

The next stage was to carry out a factor analysis of the variables to ensure that they are reliable indicators of the constructs. A cut-off loading of 0.5 was used to screen out variables that were weak indicators of the constructs. (Stevens, 1996, p. 371). For this study, Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was used (see Kaiser, 1970). Kaiser (1974) suggests that samples that have KMO values below 0.5 are unacceptable, between 0.5 and 0.7 as mediocre, between 0.7 and 0.8 as good, between 0.8 and 0.9 as great, and above 0.9 as superb. KMO measure of sampling adequacy for this analysis was >0.8.

The composite variables derived from the factor analysis formed the independent variables. Six composite variables were identified as independent variables. The dependent variable was the composite performance variable. The identified composite variables were tested for internal reliability for which all were found to have Cronbach's α exceeding 0.7 (Nunnally, 1978).

Research results

Tables I and II show the results of factor and reliability analyses. Hair *et al.* (1998, p. 111) informed that the choice of the cut-off factor loading relates to practical and statistical significance. The significance of a factor loading depends on sample size. Stevens (1996) contended that for a sample size of 100 respondents, variables with factor loadings of about 0.5 and higher are significant. For this study, a cut-off loading of 0.50 was used to screen and remove variables that were weak indicators of the constructs.

Of the 44 variables used for the factor analysis, 15 variables fail to make the cut-off, leaving 29 variables to constitute the six constructs, which are divided into "soft" and "hard" practices. The six identified constructs are: committed leadership, employee involvement, customer focus, strategic planning, knowledge management, and TPM-orientation. The dependent construct is the nine-item plant performance (Table III). The reliability values of the six independent and one dependent constructs meet or exceed Nunnally's recommended standard (Cronbach $\alpha > 0.70$) for early stage research (Nunnally, 1978).

Table IV shows the bivariate correlation matrix of the six independent and one dependent variable factors. The result of the correlation analysis is discussed in the following section.

People/customer-oriented "soft" factors and performance

The results of the bi-variate correlation analysis of this study suggest that "soft" practices are significant and positive in the relationship with plant performance. This is consistent with extant literature in management practices (Powell, 1995; Samson and Terziovski, 1999). The results of this study suggest that the "soft" practice of committed leadership has the strongest influence on plant performance than employee involvement and customer focus.

Process-oriented "hard" factors and performance

The "hard" practices indicate moderate to strong and significant correlations with plant performance. Strategic planning had moderate and significant relationships with overall performance ($r = 0.445$, $p < 0.01$). Similarly, the result also indicated moderate and significant correlations between knowledge management systems and overall performance ($r = 0.473$, $p < 0.01$). TPM-orientation had moderate to strong and significant relationships with overall performance ($r = 0.548$, $p < 0.01$).

ITEM	Factor loadings
F1: committed leadership	*Construct reliability,* $\alpha = 0.719$
q25 – actively encourage change in our plant	0.513
q29 – environmental (“green”) protection issues are proactively managed at this site	0.572
q66 – excellent occupational health and safety practices	0.552
q26 – there is a high degree of unity of purpose throughout our plant	0.595
F2: employee involvement	*Construct reliability,* $\alpha = 0.826$
q43 – there is increased employee autonomy in decision making	0.815
q45 – problems solved through small group sessions	0.761
q27 – we have eliminated barriers between individuals and/or departments	0.694
q42 – all employee suggestions are evaluated	0.631
q40 – cross-functional teams are often used	0.615
F3: customer focus	*Construct reliability,* $\alpha = 0.907$
q74 – our company actively seeks ways to meet customers’ requirements	0.861
q73 – customers’ complaints and problems are resolved promptly and efficiently	0.834
q72 – we are customer focused	0.808
q70 – we strive to be highly responsive to our customers	0.781
q69 – know our external customers’	0.632

Table I.
Factor analysis: independent variables (people/customer-oriented “soft” practices)

ITEM	Factor loadings
F4: strategic planning	*Construct reliability,* $\alpha = 0.905$
q33 – our plant has a formal strategic planning process which results in a written mission, long range goals and strategies for implementation	0.778
q34 – plant management routinely reviews and updates a long-range strategic plan	0.722
q31 – we have a written statement of strategy covering all operations which is clearly articulated and agreed to by our senior plant staff	0.706
q30 – we have a mission statement which has been communicated throughout the plant and is supported by our staff	0.589
q32 – plant’s operation effectively aligned with corporate business mission	0.564
F5: knowledge management	*Construct reliability,* $\alpha = 0.846$
q39 – we have plant-wide training and development process, including career path planning, for all our employees	0.731
q48 – we make use of benchmarking data	0.688
q47 – charts showing plant performance are posted on the plant floor	0.668
q38 – top management is committed to employee training	0.648
q65 – employee satisfaction is formally and regularly measured	0.635
q37 – ongoing education and training for all employees is encouraged	0.603
F6: TPM-orientation	*Construct reliability,* $\alpha = 0.816$
q55 – records of maintenance are kept	0.863
q56 – our plant has established a total preventive maintenance program	0.730
q53 – preventive maintenance is widely practiced in our plant	0.567
q50 – collect and analyse information on important activities	0.603

Table II.
Factor analysis: independent variables (process-oriented “hard” practices)

Table III.
Items and reliability: dependent construct (plant performance)

F9: overall plant performance	Construct reliability, $\alpha = 0.775$
q75 – has high success in meeting anti-pollution targets	
q76 – unplanned outage rate is low	
q77 – plant's unit cost of production has decreased	
q78 – have reduced the number of unit trippings	
q79 – industrial safety record is excellent	
q80 – measures in our plant that always exceed or meet environmental requirements	
q81 – plant was accident-free	
q82 – relationship with our neighborhood community is excellent	
q83 – plant production of electricity has increased	

Table IV.
Correlation matrix of constructs

Factor	F1 (IV)	F2 (IV)	F3 (IV)	F4 (IV)	F5 (IV)	F6 (IV)	F7 (DV)
F1: committed leadership	1						
F2: employee involvement	0.596**	1					
F3: customer focus	0.538**	0.469**	1				
F4: strategic planning	0.597**	0.531**	0.580**	1			
F5: knowledge management system	0.490**	0.374**	0.423**	0.659**	1		
F6: TPM-orientation	0.492**	0.335**	0.498**	0.607**	0.616**	1	
F7: plant performance	0.645**	0.407**	0.450**	0.445**	0.473*	0.548**	1

Notes: IV, Independent variable; DV, dependent variable. **Correlation significant at the 0.01 level (one-tailed)

The results of the bi-variate correlation analysis indicate that "hard" practices factors are significantly albeit with varying strengths related with performance. Of the "hard" practices factors, TPM-orientation is more highly correlated than the other two factors with performance. These results are supported by literature on maintenance practices and manufacturing performance (Brah and Chong, 2004; McKone *et al.*, 2001).

Table V shows the multiple regression of the six independent factors regressed on plant performance, F7. Together with the result of the bivariate analysis, the multiple regression analysis is used to test the *H1* and *H2* stated earlier.

Table V.
Summary of regression analysis on dependent variable, F7: overall plant performance

Analysis of variance (ANOVA)	*B*	*β*	*t*-test	Sig. *t*
Dependent variable, F7: overall plant performance				
$F(6,101) = 16.802$ (Sig. $F = 0.000$)				
Multiple $R = 0.707$, $R^2 = 0.500$, adj $R^2 = 0.470$				
Intercept	0.114		4.1095	0.000
Factor 1: committed leadership	0.443	0.481	4.779	0.000
Factor 2: employee involvement	0.021	0.025	0.271	0.787
Factor 3: customer focus	0.056	0.076	0.816	0.416
Factor 4: strategic planning	−0.107	−0.151	−1.331	0.186
Factor 5: knowledge management	0.097	0.122	1.205	0.231
Factor 6: TPM-orientation	0.228	0.282	2.871	0.005

Testing of hypotheses

Table V shows that the linear regression model (adj. $R^2 = 0.470$) explains 47.0 percent of the variation in overall plant performance. The result indicates that of the "soft" practices factors, only committed leadership exhibited highly significant and positive relationship with overall plant performance ($\beta = 0.481$, $t(101) = 4.779$, $p < 0.001$). Examination of the correlation matrix in Table IV shows that the Pearson correlation coefficients between the "soft" practices factors and plant performance are positive and significant. Committed leadership ($r = 0.645$, $p < 0.01$) has the strongest relationship among the three "soft" practices, followed by customer focus ($r = 0.450$, $p < 0.01$) and employee involvement ($r = 0.407$, $p < 0.01$). Based on the correlation analysis, all three factors are positive and significant in their relationships with overall performance. Therefore, *H1* is supported.

The results of the bi-variate correlation analysis (Table IV) indicate that TPM-orientation had a strong and significant correlation with overall plant performance ($r = 0.548$, $p < 0.001$), followed by knowledge management systems ($r = 0.473$, $p < 0.001$) and strategic planning ($r = 0.445$, $p < 0.001$). The three factors together (strategic planning, knowledge management systems, and TPM-orientation) have a greater explanatory power on overall plant performance. Based on the correlation analysis, all three "hard" factors are positive and significant in their relationship with overall plant performance. Therefore, *H2* is supported.

Validity and reliability

There is a need to determine whether the constructs of the O&M model are valid and reliable measures of the underlying practices elements. In other words, they measure what they are intended to measure. Content, construct, and criterion validities are considered (Hair *et al.*, 1998).

Content validity

A review of appropriate literature of the area of study concern contributed substantially to the content validity of the research. The elements and measurement items that make up the O&M model selected were based on extensive review of literature on TQM, human resource practices, and plant maintenance practices. The literature included major national quality awards from Malaysia, Australia, the USA, and Europe. To locate these elements and measurement items within the context of the power generation industry, appropriate literature on economic, public policy, electrical engineering, and strategy on regulated and deregulated industries was reviewed as well.

Content or face validity can be assured when there is widespread agreement generally from among the literature concerned on the various aspects of the area of study. Therefore, it is reasonable to believe that the measures of the O&M model were considered to have content validity. The items, which were developed from these sources, would clearly define the boundaries and conceptualization of the O&M model.

Construct validity

Construct validity is the extent to which an operational measure for a theoretical construct measures the defined construct (Hair *et al.*, 1998, 2003). Two checks are usually used to assess construct validity, that is, convergent and discriminant validity. The construct validity for each of the practice elements was assessed by using principal components factor analysis (Hair *et al.*, 1998). The items for each of the factors were factor analyzed (using an orthogonal Varimax rotation). Items, which had, factor loadings <0.50 were dropped. Convergent validity is then established for all the items loaded onto a particular factor (construct). Discriminant validity is also established as these items already loaded on the particular construct would not represent the other factors (constructs). Tables I and II show the results of the items and their factor loadings.

Criterion validity

Also known as predictive or external validity, criterion validity is concerned with the ability whether the construct(s) performs as expected relative with other variables of the plant performance. The result as shown in Table V produces R equals to 0.707 indicating that the six factors have a reasonably high degree of criterion-related validity when taken together and explain 47 percent of variance in plant performance. Therefore, the model has strong external validity.

Reliability

Cronbach's α is the most commonly used reliability coefficient to determine the internal consistency of a set of measurement items. Coefficient α ranges between the values 0.00-1.00. The SPSS for Windows reliability test software was used to assess separately the internal consistency of each of the factors (constructs). The results of the reliability test are shown in Tables I and II. All constructs had Cronbach's α exceeding 0.7.

Test of strength of relationship (adjustment for contextual variables)

MANOVA is an extension of the analysis of variance (ANOVA) (Hair *et al.*, 1998). It is a dependence technique that is used to assess the statistical differences between the means of two or more groups. Such groups can, as in this study, include categories on plant size, plant age groups, market environment, and technologies. It measures the differences for two or more metric dependent variables based on a set of categorical variables acting as independent variables.

Both ANOVA and MANOVA are used in this study to examine whether any statistical differences were present among the groups on the linear combination of the dependent variables. We need to control or partial out the effect of these variables before any statistical analysis such as ANOVA is carried out. This process compares the means of several of these variables, but controls for the effect of one or more other variables (Field, 2005). In this study MANCOVA is used to analyze the effects of these variables on the dependent variable. The three soft factors and three hard factors were used as covariates to explore the differences in plant organization size, plant age, and market environment and generation technology. In this study, the following contextual categories are divided into their respective groupings as follow:

1. Plant size: small (1-20 staff), medium (21-100 staff), and large ($>$ 100 staff) (Feng, 2006).
2. Plant age: group 1 (1-20 years) and group 2 ($>$20 years).
3. Market environment: group 1 (open) and group 2 (PPA-driven).
4. Generation technology: group 1 (steam turbine), group 2 (gas turbine), group 3 (combined cycle), and group 4 (hydro and others).

Comparison of the two regression equations in Tables V and VI indicates that the coefficients of the independent variables have not changed significantly. The independent variables are committed leadership, employee involvement, customer focus, strategic planning, knowledge management, and TPM-orientation. With reference to Tables V and VI,

Table VI. Summary of regression analysis on dependent variable, F7: overall plant performance with contextual variables of plant size, plant age, market type, and generation technology

Dependent variable	Parameter	Coefficient *B*	SE	*p*
Overall plant performance $R^2 = 0.512$ (Adj $R^2 = 0.472$)	Intercept	0.134	0.031	0.000
	Committed leadership	0.451	0.093	0.000
	Employee involvement	−0.025	0.084	0.769
	Customer focus	0.043	0.070	0.534
	Strategic planning	−0.070	0.084	0.410
	Knowledge management	0.106	0.080	0.191
	TPM-orientation	0.241	0.082	0.004
	Plant size – small	−0.044	0.028	0.122
	Plant size –medium	−0.022	0.025	0.373
	Plant size – large	0		
Overall plant performance $R^2 = 0.502$ (Adj $R^2 = 0.467$)	Intercept	0.127	0.033	0.000
	Committed leadership	0.451	0.093	0.000
	Employee involvement	0.016	0.078	0.837
	Customer focus	0.046	0.070	0.512
	Strategic planning	−0.099	0.082	0.230
	Knowledge management	0.096	0.080	0.234
	TPM-orientation	0.211	0.083	0.012
	Age (1-20 yrs)	−0.015	0.021	0.462
	Age (> 20 yrs)	0		
Overall plant performance $R^2 = 0.502$ (Adj $R^2 = 0.468$)	Intercept	0.125	0.031	0.000
	Committed leadership	0.451	0.093	0.000
	Employee involvement	0.026	0.077	0.737
	Customer focus	0.039	0.072	0.593
	Strategic planning	−0.102	0.081	0.209
	Knowledge management	0.106	0.081	0.194
	TPM-orientation	0.211	0.082	0.011
	Market (PPA)	−0.018	0.021	0.391
	Market (open)	0		
Overall plant performance $R^2 = 0.567$ (Adj $R^2 = 0.523$)	Intercept	0.055	0.033	0.094
	Committed leadership	0.401	0.094	0.000
	Employee involvement	0.023	0.086	0.787
	Customer focus	−0.093	0.072	0.197
	Strategic planning	−0.035	0.084	0.678
	Knowledge management	−0.018	0.086	0.831
	TPM-orientation	0.269	0.079	0.001
	Gen(ST)	0.103	0.028	0.000
	Gen(GT)	0.072	0.032	0.020
	Gen(CC)	0.073	0.029	0.014
	Gen(H&O)	0		

and comparing the *b*- and *p*-values of the estimate fitted linear models, the results indicate that there is no significant changes in both the *b*- and *p*-values between the fitted linear models when adjusted for plant size, age, market type, and generation technology.

Similarly, adjusted R^2 is not changed significantly (adj R^2 was 0.470 and 0.472 prior and after adjustment for plant organization size, adj R^2 was 0.470 and 0.467 prior and after adjustment for plant organization size, adj R^2 was 0.470 and 0.468 prior and after adjustment for market type, adj R^2 was 0.470 and 0.523 prior and after adjustment for generation technology, respectively). This shows that the explanatory power for plant performance is not changed significantly when the relationship between the O&M factors and plant performance was adjusted for plant organization size, plant age, and market type and generation technology.

Discussions of results

The results of the regression analysis show that committed leadership ($\beta = 0.481$, $t\ (101) = 4.779$, $p < 0.001$) and TPM-orientation ($\beta = 0.282$, $t(101) = 2.871$, $p < 0.001$) are significant differentiators between high and low performing power plants. The area of research on sustainable competitive advantage for organizations using the resource-based theory, either on TQM (Cua *et al.*, 2001; Powell, 1995), TPM (Brah and Chong, 2004; Cua *et al.*, 2001), JIT (Cua *et al.*, 2001), or human resource management (Huselid, 1995), have people practices as the basis of their findings or the so-called "soft" practices.

We found that the "hard" TPM-oriented practice of keeping records, total preventive maintenance, and collection and analysis of information, are also significant. High levels of leadership commitment effectively align and focus the available resources in attaining plant operational objectives, and maintenance systems or processes that involve a TPM-orientation efficiently utilize those resources in actively seeking to improve equipment and plant reliability, availability, and efficiency. This tends to produce high overall performance. It underscores the importance that both people-oriented "soft" and process/technical-oriented "hard" practices are required in order to attain high plant performance.

However, among the "soft" and "hard" practices, employee involvement has the lowest correlation with plant performance ($r = 0.407$, $p < 0.01$). This contradicts some of the earlier findings that people management score consistently higher than other factors (Powell, 1995; Samson and Terziovski, 1999). One plausible reason for the contradiction is that power plant is still managed conservatively. Though the industry had been deregulated for about ten years, remnants of the traditional management style still exist.

The majority of large power plants are still owned by power utilities or government-linked companies in Malaysia (Electricity Supply Department Energy Commission, 2004), New South Wales or Queensland (Parer, 2002). It is not surprising that plants that have been privatized such as in Victoria have achieved better performance (Tamaschke and Skoufa, 2007). Tests carried out indicate that there are significant differences in performance means between privatized and utility owned plants in terms of plant reliability ($t(3.125)$, df(68.527), $p = 0.03$) and safety records ($t(2.172)$, df(66.686), $p = 0.033$). Privatized plants may have greater degree of employee empowerment and involvement than non-privatised plants.

Conclusion

This study concludes with respect to the research question: which O&M practices are critical predictors of plant performance, that effective O&M of power plants needs to comprise both "soft" and "hard" practices in order to achieve competitive advantage in the deregulated power generation sector. Committed leadership and maintenance-oriented toward TPM were found to be the main differentiators between high and low performing plants. We also conclude that the O&M framework is a valid and reliable model for assessing plant performance. The empirical findings suggest that in addition to quality practices, which tend toward developing the people aspect of the organization, the technical aspect of plant equipment and physical assets should be given equal emphasis.

The study further concludes that the traditional O&M practices that emphasize control and command need to be changed to reflect the current situation following deregulation. Strong people-related practices and a proactive maintenance program that emphasizes preventive maintenance are the two main attributes of an effective

O&M to bring about high power plant performance. In addition to the "softer" dimensions of practices, the "harder" technically oriented dimensions of practices related to preventive maintenance are important for operational performance.

Implications for plant managers

There are several implications for plant managers. Our results confirmed that the O&M model is a valid and reliable measuring instrument for predicting the relationship between O&M and plant performance. As such, the O&M model offers a framework for power plants to assess themselves by comparing where they are relative to the "best" O&M practices. The self-assessment process should then indicate to plant managers the differences in O&M practices. It should also indicate as well the efficacy of using a TQM framework for plant improvement as practiced by some of the power plants. The self-assessment should enable a plant to identify its strengths and weaknesses so that a strategy can be formulated for improving plant performance (Evans and Lindsay, 1999).

The findings also indicate to managers that contextual factors are not strong contributors to plant performance. Nevertheless, the findings indicate that thermal plants that do not have natural constraining elements can have higher performance in terms of capacity utilization than non-thermal plants, which depend very much on the natural environment. However, the effect of these contextual factors on the strength of the relationship between O&M factors and plant performance is not significant. This indicates that internal O&M factors have more explanatory power on plant performance than contextual factors.

Limitations

Our research is cross-sectional in nature; therefore, it does not permit us to account for the lag between implementation and performance. This limitation may be overcome by conducting a longitudinal study. Second, our performance measures are subjective and may be subject to response bias. Furthermore, the introduction of competition has made the availability of objective data difficult. Third, the number of alternative renewable energy power plants in our sample is low. Renewable energy plants are growing in importance with public and energy policy maker. Further research into this area may reveal other innovative aspects of O&M practices.

Notes

1. To quote from an industry source in Australia "[…] the operators are quite 'pathological' about releasing data and information […]" (Chong Ong, Head of Victorian SP-Ausnet Network Operation).
2. Also known as frequency control ancillary services (FCAS). See glossary for explanation.
3. Also known as network control ancillary services (NCAS). See glossary for explanation.
4. See glossary for explanation.

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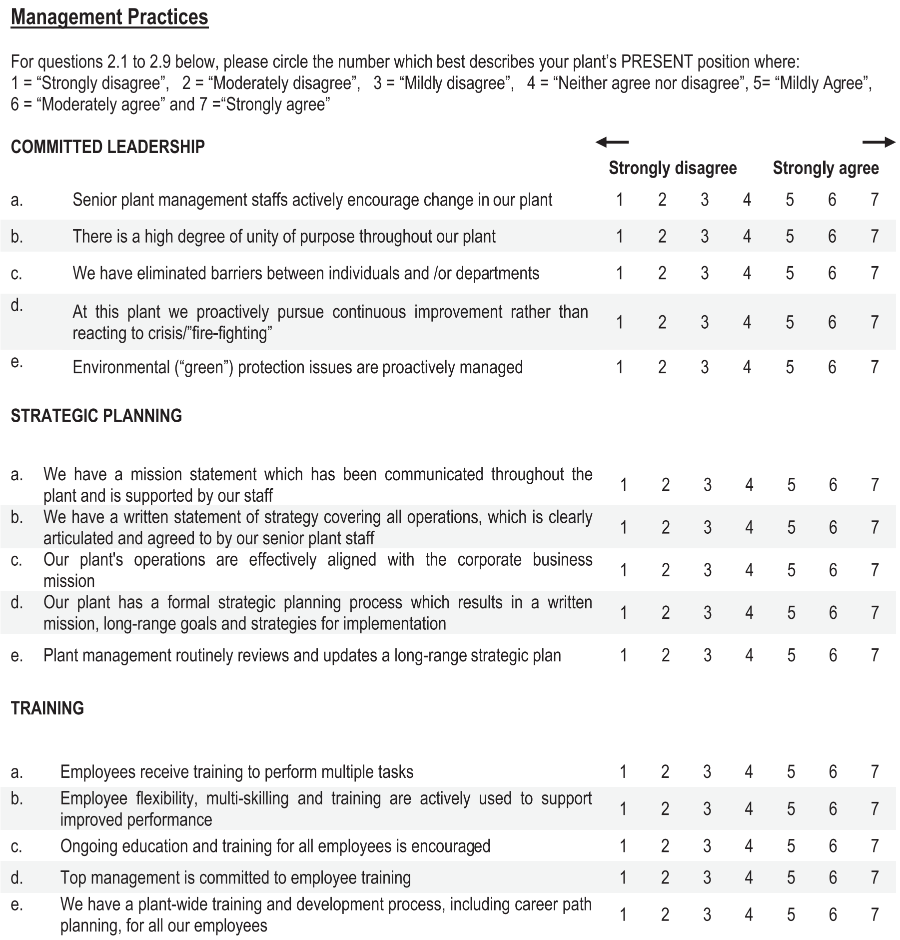
Appendix. Abbreviated survey instrument



Management Practices

For questions 2.1 to 2.9 below, please circle the number which best describes your plant's PRESENT position where:
1 = "Strongly disagree", 2 = "Moderately disagree", 3 = "Mildly disagree", 4 = "Neither agree nor disagree", 5= "Mildly Agree",
6 = "Moderately agree" and 7 ="Strongly agree"

COMMITTED LEADERSHIP

← Strongly disagree Strongly agree →

a.	Senior plant management staffs actively encourage change in our plant	1	2	3	4	5	6	7
b.	There is a high degree of unity of purpose throughout our plant	1	2	3	4	5	6	7
c.	We have eliminated barriers between individuals and /or departments	1	2	3	4	5	6	7
d.	At this plant we proactively pursue continuous improvement rather than reacting to crisis/"fire-fighting"	1	2	3	4	5	6	7
e.	Environmental ("green") protection issues are proactively managed	1	2	3	4	5	6	7

STRATEGIC PLANNING

a.	We have a mission statement which has been communicated throughout the plant and is supported by our staff	1	2	3	4	5	6	7
b.	We have a written statement of strategy covering all operations, which is clearly articulated and agreed to by our senior plant staff	1	2	3	4	5	6	7
c.	Our plant's operations are effectively aligned with the corporate business mission	1	2	3	4	5	6	7
d.	Our plant has a formal strategic planning process which results in a written mission, long-range goals and strategies for implementation	1	2	3	4	5	6	7
e.	Plant management routinely reviews and updates a long-range strategic plan	1	2	3	4	5	6	7

TRAINING

a.	Employees receive training to perform multiple tasks	1	2	3	4	5	6	7
b.	Employee flexibility, multi-skilling and training are actively used to support improved performance	1	2	3	4	5	6	7
c.	Ongoing education and training for all employees is encouraged	1	2	3	4	5	6	7
d.	Top management is committed to employee training	1	2	3	4	5	6	7
e.	We have a plant-wide training and development process, including career path planning, for all our employees	1	2	3	4	5	6	7

EMPLOYEE INVOLVEMENT

a.	Cross-functional teams are often used	1	2	3	4	5	6	7
b.	During problem solving sessions, we make an effort to get all team members' opinions and ideas before making a decision	1	2	3	4	5	6	7
c.	All employee suggestions are evaluated	1	2	3	4	5	6	7
d.	There is increased employee autonomy in decision-making	1	2	3	4	5	6	7
e.	Our staff are empowered to make decisions	1	2	3	4	5	6	7
f.	In the past 3 years, many problems have been solved through small group sessions	1	2	3	4	5	6	7

INFORMATION AND FEEDBACK

		← Strongly disagree						Strongly agree →
a.	Important data are presented and communicated to employees	1	2	3	4	5	6	7
b.	Charts showing plant performance are posted on the plant floor	1	2	3	4	5	6	7
c.	We make use of benchmarking data	1	2	3	4	5	6	7
d.	Information on productivity is readily available to employees	1	2	3	4	5	6	7
e.	We collect and analyse information on our important activities	1	2	3	4	5	6	7
f.	We have easy access to the information we need	1	2	3	4	5	6	7

PLANNED MAINTENANCE

a.	We emphasize reliability maintenance as a strategy	1	2	3	4	5	6	7
b.	Preventive maintenance is widely practiced in our plant	1	2	3	4	5	6	7
c.	Operating, maintenance, and technical personnel are fully involved in doing root cause analysis	1	2	3	4	5	6	7
d.	Records of maintenance are kept	1	2	3	4	5	6	7
e.	Our plant has established a total preventive maintenance programme	1	2	3	4	5	6	7

OPEN CULTURE

a.	We have a flat hierarchical organizational structure	1	2	3	4	5	6	7
b.	Our operation decisions are detailed in formal written reports	1	2	3	4	5	6	7
c.	We have a more open, trusting organizational culture	1	2	3	4	5	6	7
d.	In our plant there is less bureaucracy	1	2	3	4	5	6	7
e.	We often make use of empowered work teams	1	2	3	4	5	6	7
f.	There is increased staff autonomy in decision-making	1	2	3	4	5	6	7

PEOPLE MANAGEMENT

a.	The concept of the "internal customer" is well understood at this plant	1	2	3	4	5	6	7
b.	Our site has effective "top-down" and "bottom-up" communication	1	2	3	4	5	6	7
c.	Employee satisfaction is formally and regularly measured	1	2	3	4	5	6	7
d.	Our Occupational Health and Safety practices are excellent	1	2	3	4	5	6	7
e.	Reward and recognition systems support the plant's performance objectives	1	2	3	4	5	6	7
f.	We have internal promotion of staff	1	2	3	4	5	6	7

CUSTOMER FOCUS

a.	We know our external customers' current and future requirements	1	2	3	4	5	6	7
b.	We strive to be highly responsive to our customers' needs	1	2	3	4	5	6	7
c.	We regularly measure external customer satisfaction	1	2	3	4	5	6	7
d.	We are customer focussed	1	2	3	4	5	6	7
e.	Customers' complaints and problems are resolved promptly and efficiently	1	2	3	4	5	6	7
f.	Our company actively seeksways to meet customers' requirements	1	2	3	4	5	6	7

PLANT PERFORMANCE

For question (1) below, please circle the number which best describes your plant's PRESENT position:
1 = "Strong y disagree", 2 = "Moderately disagree", 3 = "Mildly disagree", 4 = "Neither agree nor disagree", 5= "Mildly Agree",
6 = "Moderately agree" and 7 = "Strongly agree"

		Strongly disagree ←						Strongly agree →
1.	Over the past three years, . . .							
a.	…. our plant has high success in meeting anti-pollution targets	1	2	3	4	5	6	7
b.	…..our plant unplanned outagerate is low	1	2	3	4	5	6	7
c.	…..our plant's unit cost of production has decreased	1	2	3	4	5	6	7
d.	…..we have reduced the number of unit trippings	1	2	3	4	5	6	7
e.	…..our industrial safety record is excellent	1	2	3	4	5	6	7
f.	….we have put in place measures in our plant that always exceed or meet environmental requirements	1	2	3	4	5	6	7
g.	…. our plant was "accident-free"	1	2	3	4	5	6	7
h.	…..our relationship with our neighborhood community is excellent	1	2	3	4	5	6	7
i.	….our plant production of electricity has increased	1	2	3	4	5	6	7

2. Please indicate your plant's current performance level for EACH of the indicators by writing down a single number, ranging from 1 through 7, in the vacant end column.

	Indicators	1	2	3	4	5	6	7	(1-7)
A	Average annual plant capacity factor % for the past three financial years	<10	11-20	21-40	41-60	61-80	81-95	>95	
B	Average annual Plant Equivalent Availability factor % for the past three financial years	<50	51-60	61-70	71-80	81-90	91-95	>95	

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