Facility Management Benchmarking: Measuring Performances Using Multi-Attribute Decision Tools

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A thesis submitted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy

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CERTIFICATE OF ORIGINALITY

I hereby declare that this submission is my own work and to the best of my knowledge and belief, it contains no materials previously published or written by another person, nor material which to a substantial extent has been accepted for the award of any other degree or diploma at any educational institution, except where due acknowledgement is made in the thesis. Any contribution made to the research by others, with whom I have worked at The Hong Kong Polytechnic University or elsewhere, is explicitly acknowledged in the thesis.

I also declare that the intellectual content of this thesis is the product of my own work, except to the extent that assistance from others in the project's design and conception or in style, presentation and linguistic expression is acknowledged.

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ABSTRACT

Abstract of thesis entitled : Facility Management Benchmarking: Measuring Performances Using Multi-Attribute Decision Tools

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The aim of this research is to develop and demonstrate the applicability of three different decision tools in facility management benchmarking. The three tools are Analytic Hierarchy Process (AHP), Data Envelopment Analysis (DEA) and regression analysis.

Within this research, facility management is defined as a process of service operations which an organization should benchmark to improve the performance of its core business.

There is a rich body of literature on performance measurement, facility management, benchmarking, and decision tools. However, there is a lack of understanding of how the most useful information and knowledge can be acquired through facility management benchmarking with the application of decision tools.

Since the early 1990s, research in Facility Management and Benchmarking has stressed the importance of objective measurement based on objective and subjective data (Kincaid (1994)). This research presents methods which show how the data could be integrated for improvement execution.

The performance of facility management is multi-dimensional and should cover both hard aspects such as operations costs, and soft aspects such as customer satisfaction measurements. Analysis of soft data was carried out with AHP and regression analysis. The relationships between various hard data and soft data were examined by DEA.

As a process of service operations, facility management is interpreted as an input-output system which can be assessed by DEA in terms of productivity. As with many service industries, customer satisfaction is an important factor within the input-output system. This explains the need for applying decision tools for facility management benchmarking. The decision tools assist facility managers in analyzing customer satisfaction. AHP and regression analysis are identified as appropriate tools to analyze other soft data. The theoretical discussions are supported by two case studies.

This research shows how the proposed tools can be applied to improve the optimization of resources of facility management units and thus improve their competitiveness. The proposed tools point out the relevance of some implications from collected data. Facility managers can identify not only the inefficiencies but are also given hints on the ways to catch up with their efficient peers. Based on the case studies, this research found that the tools could work with soft and hard data of facility management and clearly indicate need for improvements.

Data collection was limited to facility management units in Hong Kong and the South Pacific region. Nevertheless, the tools have global applicability.

This study reveals the inconsistency of the customers' perceptions on facility management quality. It also confirms the benefits of consistency test of AHP to the process of decision making in Facility Management planning. With reference to the conventional performance-gap analysis by comparison, significant improvements are made to the analysis methodology by introducing the concepts of matching between soft and hard data and correlating AHP and regression results.

The major contributions to knowledge from this research are summarized as follows:

1. Integration of the knowledge of decision tools with that of facility management benchmarking.

2. Provision of comprehensive design principles for a facility management benchmarking framework targeted to the acquisition of a maximum amount of knowledge for business improvement.

3. Assistance to facility managers to develop a clear picture of their facility's operation and customers' demands with the proposed decision tools.

DEDICATION

To
Casper, Jessica, Richard and my parents

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Chapter 1 –Introduction

Both Facility Management (FM) and benchmarking are diverse subjects. FM professionals serve in the fields of property management, built environment, catering, cleaning, security and engineering services. Researchers working in the fields of benchmarking include accounting, operations management, marketing, finance, economics, psychology and sociology subjects. Few interactions between FM and benchmarking are evidenced when compared to production and benchmarking or services and benchmarking. The situation is more obvious in the Asia Pacific region. (Ho *et al.* 2000)

Friday and Cotts (1995) emphasize Total Quality Management (TQM) and its impact on FM customers as a primary focus for FM. The International Facility Management Association (IFMA) also highlights quality assessment and innovation with respect to benchmarking as one of eight key competency areas for facility managers. In spite of the importance of FM benchmarking, many organizations choose to ignore benchmarking (Loosemore and Hsin (2001); Alexander (1996); Varcoe (1996)) when compared to other sectors such as higher education (Fram and Camp, 1995), manufacturing (Voss *et al.* 1994), portfolio performance (Grinblatt and Titman 1993) and human resources (Martinsons 1994). As a result, missed opportunities abound.

For consistency throughout this study, FM is defined as the service related to the built environment to provide occupants with a pleasant and productive environment, under which commercial occupants can concentrate their resources on their core business and residential occupants can enjoy their living space. To achieve this objective, facility managers should integrate the built environment with multi-disciplinary activities, e.g. business administration, architecture and behavioral and engineering sciences.

In the arena of FM, benchmarking may be defined as a continuous and systematic approach for measuring and comparing the work processes of one organization with those of another by bringing an external focus to the internal FM activities, functions or operations. It is indeed a learning and improvement process through measuring and comparing both quantitative and qualitative aspects of the organization.

Evidence indicates that organizations using balanced performance measurement systems as the basic for effective management tend to do better than those without (Lingle and Schiemann, 1996). However, for the advantages to be realized, it is necessary for an organization to implement benchmarking to "*enable informed decisions to be made and actions to be taken because it quantifies the efficiencies and effectiveness of past actions through acquisition, collation, sorting, analysis, interpretation and dissemination of appropriate data*" (Neely, 1998). By demonstrating the cause and effect, facility managers are well placed to influence corporate executives to adopt FM improvement measures.

1.1 Why Benchmark?

Effective FM planning and review can be a source of sustainable competitive advantage. An effective FM review requires a commitment to continuous improvement. All medium or large organizations perform some type of FM planning and review, whether it consists of an annual meeting where various departments participate to agree on the FM plan, or a full-time staff that simulates alternative scenarios based on projected needs. For every company, the question is the same: How can improvements be made?

The first step is to understand where an FM unit is – that is, to uncover the current performance. A facility manager needs to understand the context of relevant FM information by comparing delivery performance with a standard. Facility managers require a benchmark comparing performance to similar companies or, preferably, to a best-in-class standard.

As Camp (1989) indicated, benchmarking is the search for those best practices that will lead to the superior performance of a company. Investors and shareholders demand that companies use capital more effectively, which increases the pressure to rapidly match deployed assets to market needs. Growth or improvement, compared to previous years, is always expected. Corporate executives and facility managers are required to facilitate this expected growth. Benchmarking is the key to measure performance and compare corporate performance in order to identify best practice.

DeVries (2002) identified six reasons to benchmark:

1. Develop and implement strategic goals;
2. Establish realistic and actionable objectives;
3. Provide a sense of urgency;
4. Encourage striving, innovative, and out-of-the-box thinking;
5. Create a better understanding of the industry;
6. Emphasize sensitivity to changing needs of customers.

The six reasons put forward by DeVries (2002) are also elaborated in FM literature, e.g. Then (1996) identified two basic benchmarking drivers, i.e. increased/new competition, improving efficiency and effectiveness. Then also highlighted the importance of benchmarking as a powerful business improvement tool, emphasized the strategic importance and distinct characteristics of benchmarking results of practicability and timeliness.

1.2 The Need to Benchmark Facility Management

Apart from making improvements, benchmarking is an important practice to FM business. Measurements related to workspace size, occupation density, quality of lighting and air-conditioning, etc. are all essential for efficient FM. Management of outsourced FM services also calls for such data and information. In addition, data collected from current FM performance in the process of benchmarking helps clients determine specifications of the service level agreements and to set up Key Performance Indicators. Benchmarking enables facility managers to better understand what they do, compare themselves with others, determine whether FM processes are in control, identify the need for change, forecast the benefits of change and lastly to make informed decisions (Kincaid 1994).

1.3 Facility Management Quality and Perception

Some forms of ‘excellence’ (a popular word of business management from the 1980s) are expected when FM quality is discussed. As Valence (2003) pointed out, FM quality should cover the existence of a standard or the setting which meets the customer expectation and reflects the needs of business and customers. Supported by literature related to management of services and product quality, Valence related customers’ satisfaction of FM to the perceived quality that customers get.

Intangibility and the multi-dimensional nature of FM causes problems related to quality measurement and specification. According to interviews with FM professionals, two basic questions for facility managers were identified:

1) Are we producing a quality FM service?

2) How well are we using our resources to produce the service?

As proposed by Hope and Muhlemann (1997), quality measurement of service operations management may be expressed as:

1) Ask questions related to expectations of the service;

2) Repeat the same questions but ask the perceptions of actual service received;

3) Determine the relative importance of the information.

1.4 Facility Management and the costs

Low cost and product (or service) differentiation are the two main types of competitiveness in the retailing industry. Porter (1985) suggested that these two competitive advantages could be considered in broad and narrow ranges. Three key generic competitive strategies are found: cost leadership, differentiation and focus. Their positions are illustrated in Figure 1.1.

		Competitive Advantage	
		Low cost	Differentiation
Competitive Range	Broad	Cost leadership	Differentiation
	Narrow	Cost focus	Differentiation

Figure 1.1 Positioning of Generic Strategies (Adapted from Porter (1985))

To apply the above strategic map to the FM industry, the benefits of cost leadership are obvious for FM services providers: good profits and strong positions on price adjustment in the market, and increased market share. For in-house FM units, cost leadership means flexibility and better bargaining power with the executive level. Benchmarking may also help both the in-house FM units and FM services providers answer the following questions:

a) What is baseline cost?

b) What is the risk of cutting costs or outsourcing?

c) What are the estimated future costs and how accurate is the estimation?

d) How can providers limit differences between bid price and actual price?

Although intangibles within FM service can offer great potential for differentiation, e.g. appearance and scale of services, based on the discussion with FM practitioners and case studies in this research, FM costs are the main subjects in all FM benchmarking studies.

1.5 Objectives of this Study

The objectives of this study are to examine the common technical problems in the process of FM benchmarking. Through case studies, this study examines the following issues in FM benchmarking:

- Matching soft and hard data in the FM benchmarking process: Inter-relationships among soft and hard data should be reflected and interpreted when benchmarking;
- Integrating FM data and information: FM operation is interpreted as an input-output transformation process;
- Analyzing effects of input & output mix allocative efficiencies on FM benchmarking: Comparison results are interpreted and applied;
- Analyzing FM data & information characteristics: Performance measurement by relative values and absolute values;

- The relative importance of individual FM service from a facility manager and a customer perspective;
- Application of decision-making tools in FM benchmarking study.

1.6 Scope of Study

The method adopted in the research involves cross-sectional case studies conducted through a customer satisfaction survey of 14 buildings under the management of a local FM unit and a benchmarking study with the participation of 72 global educational institutions. This approach facilitated the study of decision-making tools on FM benchmarking.

The two projects were studied in detail. This involved three aspects of FM operation and benchmarking: 1) productivity and efficiency, 2) effectiveness of benchmarking, and 3) stability of benchmarking results. The facility managers involved in the two projects were interviewed during the course of the study.

1.7 Outline of the Study

The framework for this study was largely derived from the literature. The conceptual framework for this study is shown in Figure 1.2, and the framework does not imply any causal relationships. This research attempted to identify significant associations between the different factors in the following study framework.

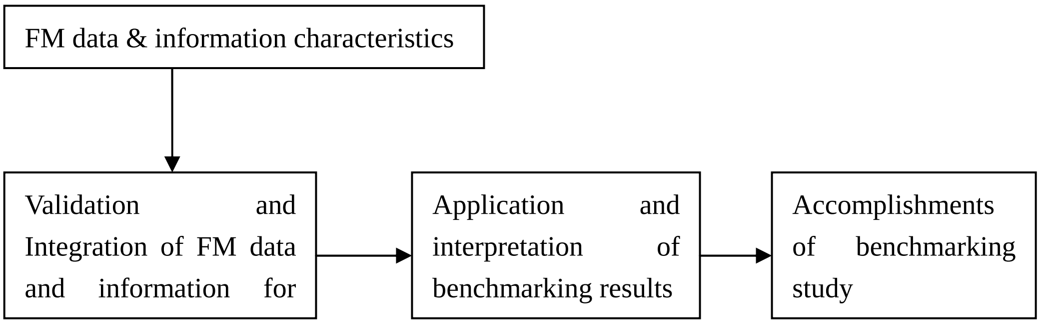

Figure 1.2 Framework for this study

In line with the above figure, it is noted that FM data and information for benchmarking solely based on accounting information does not reflect many aspects of FM operations and may neglect important differences between various forms of FM businesses. For instance, accounting data usually does not capture information on the number of FM employees and the distribution of resources in different cost centres. It is noted that many FM operations are outsourced and costs of different outsourcing contracts are often put in different categories and take time to trace. For example, contracts for hiring security guards and consulting contracts for auditing security systems are substantially different. The former are subject to areas of premise and customer requirements while the latter largely depends on legal requirements, core business necessity and policy at executive level. Attention is required when costs on these different contracts are analyzed or integrated.

Another example in the hotel sector was noted by Wober (2002). Financial reports do not indicate the number of overnights generated during the fiscal year, nor do they give information about the available (maximum) capacities. Therefore, an even simple calculation related to productivity ratios requires additional information on other business characteristics.

Complete FM benchmarking study may require the FM units of participating organizations to record operations data over time. In so doing, significant resources over a considerable time should be committed. This may explain why most benchmarking literature focuses on large enterprises.

Benchmarking literature, especially those related to customer satisfaction, indicates that too many questions often relate in absolute terms to qualitative and subjective judgments. As illustrated by Triantaphyllou (2000), such questions are better dealt with on relative terms. An illustration is given below:

Suppose a participant gave the following weights:

W_1, Convenience with respect to their locations = 0.3;

W_2, Rent = 0.5;

Furthermore, suppose that the participant changed the weight $W_1' = 0.35$; $W_2' = 0.57$.

In absolute terms, the critical change for Convenience ($|W_1 - W_1'|$ i.e. 0.05) is smaller than that for Rent ($|W_2 - W_2'|$ i.e. 0.07).

In relative terms, the above conclusion reverses:

Change of weight for Convenience is $|W_1 - W_1'| / W_1$ i.e. 16.67%;

Change of weight for Rent is $|W_2 - W_2'| / W_2$ i.e. 14.00%.

The difference may have further implications for sensitivity analysis. A change of 0.05 is more meaningful for the original value of 0.3. In the above example, it is more appropriate to use relative terms. Since the objective of benchmarking is to excel against one's peers, judgment in terms of relative sense is more suitable than a subjective reference scale which may be very different for individual participants.

Integration of FM data and information is common when comparison of overall FM performance is made. Past studies of FM benchmarking have focused on the development of standard benchmarking metrics or Key Performance Indicators (KPI) of FM. For example, Hinks and McNay (1999) showed, by Delphi method, the process of developing 23 FM KPI for benchmarking with suggested weights.

Similarly, Ho (2000) put forward a list of KPI used by Facility Managers in Asia. These studies did not explore the technical difficulties faced by Facility Managers in the process of benchmarking.

One benchmarking difficulty is the integration of qualitative and quantitative aspects of FM. For example, by reducing the inputs of human resources and security expenditures, an FM unit can still serve a building with the same number of visitors and lessees, but the FM unit may have given up customer satisfaction, safety level and commercial reputation.

As illustrated by case studies, the integration may be investigated through an input and output transformation process as services operations management, with reference to Hope and Muhlemann (1997).

Apart from linking benchmarking results, measurement metrics with financial returns, Facility Managers should be able to differentiate between KPI (indicative of associated future performance), KPO (Key Performance Observation, measures of completed events), and perception measures (individual judgments), and also ensure that measures developed include all types of measure, Beatham *et al* (2004).

In this research, Data Envelopment Analysis (DEA) is proposed as an integration tool of qualitative and quantitative aspects of FM. Analytic Hierarchy Process (AHP) can be applied for analyzing qualitative information, and AHP may also be applied to identify some inconsistent qualitative information.

<u>Application and interpretation:</u> Assume FM operations may be interpreted as an input and output transformation process in the process of benchmarking, with reference to Coelli *et al* (2003). With multiple inputs and multiple outputs, it is submitted that FM units' different performance in terms of productivity is due to four reasons:

1. Technical Efficiency (TE): TE is often understood as a technical change or technological progress. It represents an increase in the maximum output, which can be produced without changes of an input vector.

2. Scale Efficiency (SE): SE is a measure of the degree to which a unit is optimizing the size of its operations. A unit may be too small or too large, resulting in a 'productivity penalty'.
3. Input mix Allocative Efficiency (AE): AE is a unit's ability to select the correct mix of input quantities to ensure that the input price ratios equal the ratios of the corresponding material products or services. AE score varies between 0 and 1, with a value of 1 indicating full allocative efficiency.
4. Output mix allocative efficiency: This is a unit's ability to choose the combination of outputs quantities in a way that ensures the ratio of output prices equals the ratio of marginal costs, that is, the additional cost corresponding to the production of an additional unit of product.

A unit which is technically efficient, efficient on scale and achieves input mix and output mix allocative efficiency is maximizing returns for given inputs and outputs.

In this research, Data Envelopment Analysis (DEA) is proposed as an application tool for FM benchmarking in an input and output transformation process.

At the outset of the research, the following problem statement is submitted:

> *Currently there is no adequate benchmarking tools available which have been proved to guide Facility Managers to manipulate benchmarking metrics, the information and their inter-relationships. This difficulty largely explains many problems in the FM benchmarking process.*

1.8 The Research Problem

Most facility managers acknowledge that benchmarking accelerates innovation and change leading towards improvement. However, return of investment on a benchmarking project often depends on detailed planning and analysis.

Assuming customers, service operation processes and critical success factors are identified, data collection and analysis then commence in the execution of benchmarking. At this stage, a facility manager faces technical problems of organizing, interpreting and presenting data. Unlike, for example, retailing or production, for facility managers deriving the solution for these problems are not simple. Whereas for retailing or production, a benchmarking solution may be derived from a regression model:

$$\text{Sales (\$)} = a + b*\text{price} + c*\text{coupons} + d*\text{advertising} + e*\text{price}*\text{advertising}$$

where a, b, c, d, and e are constants.

However, a simple regression model, similar to above, is unlikely to be adequate for FM benchmarking owing to the need for implementation. Implementation is a critical step to fulfill the benchmarking objective. Fleming (2005) put forward the importance of customer perception to the assessment of the workplace. A systematic approach is required to relate improvement policies with data and information to be deduced from the benchmarking analysis.

1.9 Research Questions and Hypotheses

This study attempts to further advance frontier knowledge about FM benchmarking. The key questions which guide and direct this research are identified as below.

Research Question Group 1: Based on case studies in this research, what are the technical problems in the process of FM Benchmarking?

Hypothesis 1: Outsourcing, specifications development and other common FM practices pose a paradox for FM benchmarking. For example, outsourcing agreements often cover service charges based on area and service levels, which frequently involve ambiguity, Rees 1999. DEA & AHP can be applied to offer a clearer picture.

Research Question Group 2: What is the association between the amounts, dimensions of information and implications deduced from benchmarking study, and the improvements made afterwards? Can the proposed benchmarking tools make any difference or contribution?

Background: With reference to literature produced by organizations of different professions, e.g. IFMA (2001) and Air Transport Research Society (2003), many benchmarking studies stopped after data collection and comparison. Achievements of many benchmarking projects often turn out to be a reference tool for the professions.

Hypothesis 2: The amounts and dimensions of relevant information deduced from the benchmarking study are positively associated with the accomplishments of benchmarking projects.

Hypothesis 3: Periodic benchmarking or performance measurements are good tools of indications, especially when wrong steps are just made.

Hypothesis 4: DEA and AHP can offer more guidelines for many FM improvement policies. Risks of improvements executions can be reduced.

Research Question Group 3: Do current FM benchmarking tools give enough information for improvement implementation to achieve best practice among peers? What additional information can be given by the proposed benchmarking tools?

Background: Based on the author's experience and from the literature on FM, tools applied by facility managers in benchmarking mainly focus on data collection and processing for graphical interpretation. Common applications of IT or mathematical tools in FM benchmarking may be found in a conference paper by Hoots (2003). For example, a weighted FM factor comparison chart is applied to rate contractors' performance. Few mathematical or IT tools, if any, are applied by facility managers for benchmarking analysis. In tourism and hospitality industries, information and database systems, incorporated with mathematical tools, are applied for benchmarking. The International Hotels Environment Initiative and the World Wildlife Fund in the UK developed the 'Environmental Benchmarking Tool'. Hotels can use benchmarkhotel.com to monitor their energy management, fresh water consumption, waste management, waste water quality, purchasing programme, community relations and bio-diversity improvement.

Hypothesis 5: Popular 'tools' currently used by facility managers, like spectrum diagrams, flowcharts for the benchmarking-partner selection process, scorecard, shaded circles for portraying scorecard-type results, bar chart, polar graph (as introduced by Razmi *et al.* (2000)), can only improve clarity in the decision-making process and allow better presentation. They cannot perform in-depth analysis for FM benchmarking for achieving the best among peers.

Hypothesis 6: By taking FM inputs and turning these to outputs, the proposed benchmarking tools can locate ways of improvement. It can give facility managers guidelines by investigating the possible source of inefficiencies with reference to the efficiency reference set.

1.10 Thesis Structure

Two themes, FM performance and benchmarking, are treated in the introductory chapters to provide the necessary background for the presentation of the proposed benchmarking methodology in Chapter 4. The analysis and subsequent discussion of case studies will follow. The thesis closes with a discussion on case study results and conclusions from the research. The structure is shown in Figure 1.3.

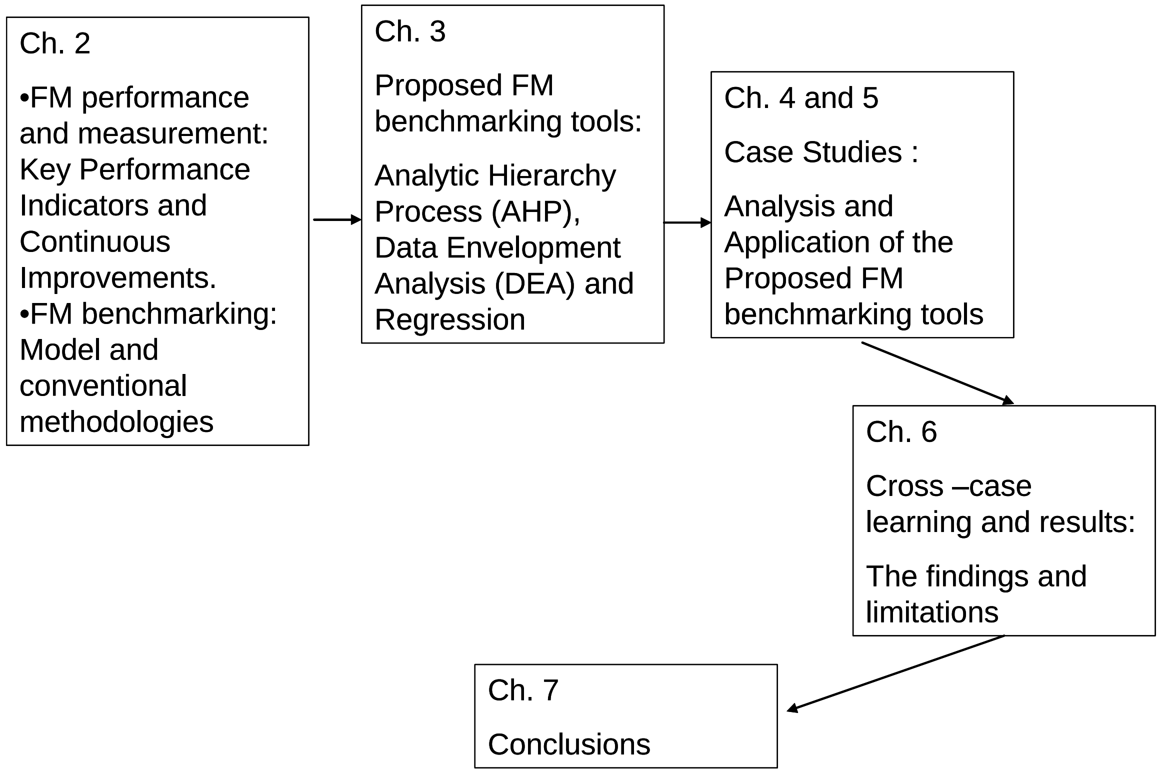

Figure 1.3 Thesis Map

Chapter 2 – Facility Management: Performance Measurement and Benchmarking

2.1 Facility Management: A Service Operations Management

From the mid-1990s, Facility Management (FM) has developed as a mainstream service sector employer. In the UK it is supported by a strong national institute, the British Institute of Facilities Management whose membership is almost 10,000. FM has also developed within other professional organizations, like the Royal Institution of Chartered Surveyors, the Chartered Institution of Building Services Engineers and the Chartered Institute of Building. The International Facility Management Association (IFMA) based in North America has 17,500 members worldwide (Source: http://www.ifma.org). Typically, FM covers a range of skills including property management, built environment, catering, cleaning, security and engineering services. With reference to the survey on labour carried out by the Census and Statistics Department of the Hong Kong Government, the FM industry represents more than 10% of Hong Kong's labour force (Census and Statistics Department, Hong Kong Government 2004, source: http://www.info.gov.hk/censtatd/eng/hkstat/hkinf/labour_index.html). In Hong Kong, most FM categories are defined within the services sector.

McLennan (2004) notes four characteristics of services operation which have long been performed in the FM industry and argues that FM has been developing within service operations management. The four characteristics are:

1. FM services are often heterogeneous as no two customers are alike, each having individual requirements. This proposition is proved by examples of hotels and hospitals. FM services are tailor-made services.
2. FM services are consumed in the space of production, i.e. intangible.
3. Most FM services are with high customer contact within the space where services are consumed, indicating simultaneous production and consumption.
4. FM services are 'time sensitive' and cannot be stored by consumers and services providers.

McLennan's observations support the idea that many existing concepts, techniques and models which have been applied in service operations management may be applicable to the FM industry. For example, there are many successful attempts in the use of operation management techniques in the services industry, e.g. benchmarking in both the banking and retailing industries (Stone (1996)).

2.2 Benchmarking

Benchmarking is commonly initiated with one or more of the following objectives:

A) To accelerate the rate of the improvement cycle: A tested improvement scheme can be implemented with minor adjustment. Investments of time and money on unnecessary experiments are saved. (Johnson (1998))

   For example, two similar FM units (A and B) study their energy consumption, energy saving policies and their implication through benchmarking. As a result of the study, it is determined that unit A performs better than unit B. The study indicates that improvement can be made by the adoption of high efficiency electrical appliances of unit A. Thus unit B may seek improvements by adopting similar practices.

B) To identify best practice: By comparing the results, like the amount of each sales dollar spent on labour, best practices are identified and learnt from peers.

C) To lower risks in the process of improvement implementation: Adopting new measures or policies entails risk. The more aggressive and fast-paced the changes, the greater the potential for a misstep. By learning from others' experience, the risks resulting in the process of learning and improvement can be minimized.

D) To improve the quality of decision-making for improvement: With figures and records, most decisions are substantiated with a strong base and mistakes can be traced.

E) To identify metrics for comparison: Sales volume, profits and return on equity are common metrics of measurement in all commercial sectors. In the service industry, customer satisfaction and the number of complaints should be measured with a flexible but commonly accepted standard.

F) To encourage new ideas and innovation by competition: In the process of benchmarking, managers perform research on benchmarking peers. New ideas are often generated when benchmarking peers are from other industries.

G) To set and adjust goals of learning process: John Browne, the current CEO of British Petroleum, commented on how to motivate people to excel at learning in an interview with the Harvard Business Review ((Prokesch (1997)),

> "*To get people to learn, you need to give them a challenge. Setting a target is crucial even if you don't actually know whether it's fully achievable*".

The comparison between goal and actual performance leads managers to review (Simmons (1999)) on:

1. Assumptions and standards made;

2. Cause and effect relationships;

3. The validity of intended strategy; and

4. The effectiveness and efficiency of strategy implementation.

H) To set up systematic cooperation among organizations for mutual enhancement: For example, many professions, such as engineers, medical doctors and facility managers, have formed professional associations or institutions. These interest groups share information through casual interchange or more formally by developing benchmarking circles or clubs. For example, the IFMA publishes benchmarking reports on a regular basic in an attempt that their members can have updated and relevant benchmarks commonly applied in the FM industry.

I) To assess or predict contractors' performance. This is not an objective directly related to improvement or learning but it shares the same five phases of benchmarking. Unlike situations where an organization joins and shares data and information, employers take the lead to benchmark their contractors or potential contractors. For example Sino Group, a Hong Kong listed estate-development company, has formed a benchmarking team to assess and screen applicants for their outsourced projects. However, it should be noted that if the major objective of benchmarking is for assessment, it may be argued that it is not a complete benchmarking process.

2.2.1 History of Benchmarking

The concept of benchmarking can be traced back about two thousand years. 'Benchmark' is a term used in land surveying. It is a sighting point from which measurements can be made.

The two important predecessors to the current benchmarking approach are competitive analysis and quality function deployment (QFD). Competitive analysis is applied as a means of collecting data and measurement usually with respect to markets, sales, products, production costs, or budgets of competitors. Although competitive analysis is useful in assessing one's position relative to competitors, it seldom provides insights as to how competitors achieve this position, i.e. by what methods or processes. In contrast, the benchmarking process goes beyond comparison of results and includes analysis of organizational processes and methods (Fitz-enz (1993)).

QFD is an approach for product development that allows an organization to interpret customer needs and expectations and state them in terms of technical requirements (Kogure & Akao (1983)). This approach originated in Japan at the Kobe Shipyard of Mitsubishi Heavy Industries Ltd in the early 1970s (Automotive Engineering (1988); Kogure & Akao (1983); Sullivan (1986)).

The first systematic benchmarking project was initiated by Xerox Corporation in 1979 (Camp (1989). The project was triggered by a belief that production costs of photocopiers were significantly lower in Japan. Xerox gained an insight into the production process of Japanese photocopier manufacturers. This competitive benchmarking project enabled Xerox' big improvement in design, production efficiency, and cost control (Camp (1989); Spendolini (1992)).

Camp (1995) proposes five main phases for benchmarking: (1) Planning: Identify what to benchmark, whom to benchmark and collect data from; (2) Analysis: Examine the performance gap; (3) Integration: Communicate the findings and develop new goals; (4) Action: Take actions, monitor progress, and recalibrate measures as needed and (5) Maturity: Achieve the desired state.

The Malcolm Baldrige National Quality Award is also associated with the development of benchmarking:

a) The award receivers are required to share information regarding quality and business process improvements with others. In so doing, a source of benchmarking data was created.

b) All participants are required to implement and maintain trend data and conduct comparison. This requirement helps participating organizations create a culture of sustaining benchmarking (Czuchry *et al*. (1995)).

Nowadays, benchmarking is a widely accepted business practice. The applied art of benchmarking has become broader in nature to cover business strategies (Yasin (2002)).

2.2.2 Types of Benchmarking

Classification of benchmarking is often based on [1] who benchmarking is performed against i.e., internal and external benchmarking (Zairi (1992)); and [2] the level within the organization structure that the benchmark focuses on benchmarking with respect to strategy, performance and process (Rainey (1997)).

Ettore (1994) illustrated an example of external benchmarking (generic type) with German generals who observed an American circus before the First World War. A circus is expert at moving great quantities of animals, people, food, and gear; assembling and disassembling the shows; and traveling from city to city within a short time. The military has the same logistical issues: moving masses of people, horses, ammunition, and food quickly and efficiently. These military administrators learned deployment proficiency from unrelated sources, one whose purpose and mission were very different. Often, significant breakthroughs are made when organizations benchmark not just their competitors, but businesses in other industries.

There are different kinds of external benchmarking:

- Competitive: Comparisons are made among competitors. This could be the most beneficial kind of benchmarking despite the difficulty of data collection.
- Functional: Comparison of particular functions' performance within organizations that have similar functions but are not necessarily competitors.
- Generic: Organizations look at individual processes in any kind of organization which may be outside of its industry. The above–mentioned example where

German military administrator learnt logistics practice from American circus is a case of generic external benchmarking.

Internal benchmarking is usually made by organizations to compare areas, processes or departments within itself. The popularity of internal benchmarking can be explained by the convenience of its application: common culture and ‘language’, the ease of data assessment, good communication and relative speed of its performance. The disadvantages of internal benchmarking come from the lack of external focus. Learning gaps are confined within the organization. Comparison cannot be made externally against competitors. Commonly used benchmarks, like market share, are difficult to study with internal benchmarking results.

Strategic benchmarking measures the success of a policy that addresses broad organizational goals to determine the best strategic outcomes of the class. This kind of benchmarking is seldom industry-focused. Performance benchmarks compare accomplishment among similar programs. This benchmark usually focuses on elements of price, technical quality, services features and reliability, which is the focus of the proposed benchmarking framework for FM in this thesis. Process benchmarking compared through identification of the most effective operating practices from other organizations that perform similar work processes.

A benchmarking exercise may cover one or more of the above types. The adopted approach depends on the objective of the exercise.

2.3 FM Benchmarking

The objectives of benchmarking studies most commonly carried out in other sectors, which were discussed in paragraph 2.2, are true in the case of FM benchmarking. The differences between FM benchmarking and the application of benchmarking in other sectors may be summarized as below:

1) A complete FM Benchmarking study should not just cover conventional property

performance, e.g. flexibility of systems, cost of equipment & maintenance, but also include metrics which interpret the customers' needs. As Shaw and Haynes (2004) argue, to develop FM, benchmarking has to change from a system based on simple cost and benefit measurement or other financial terms towards one with a customer-focused component.

2) Since the objective of FM is to support an organization's business, an FM unit typically has to develop a strategic management vision in line with its serving organization.

3) Douglas (1996) highlighted the three basic functions of buildings: (1) enclosure of space; (2) climate barrier-modifier; and (3) protection and privacy. Apart from the interrelations of these three functions, what makes FM benchmarking more complicated than other applications of benchmarking is the involvement of human behaviors, and various human activities call for disparate requirements. Customers' requirements on facilities can be analyzed in four perspectives:

   i. Environment: Facilities shall provide suitable internal environments for the people, their activities and tasks carried out and commodities to be housed under controlled conditions without the adverse effects of external conditions.

   ii. Finance: Facilities are assets with capital growth potential.

   iii. Culture and pride: Facilities reflect architectural aspirations and historical characteristics.

   iv. Legal requirements: Some facilities enable owners and users to comply with certain statutory requirements.

4) The importance and uniqueness of FM has been long recognized in the US and Europe. However, FM in Hong Kong has only grown in significance during the last ten years (Lomas (1999)). For example, most Hong Kong estate developers have established one or more management arms to manage their property

portfolios. Recently businesses unrelated to property or estate development, such as logistics company Crown Worldwide headquartered in Hong Kong, have also started to form their FM division or department, instead of nesting them directly under their administrative arms.

5) Despite many FM researchers' and practitioners' efforts, FM has yet to be defined with universal acceptance. Some researchers (e.g. Nutt (2000)) tried different methods to define FM and its measurement metrics for the purpose of benchmarking. For example, Hinks & McNay (1999) put forward a process of developing a management-by-variance tool for monitoring the performance of the FM function of a major financial services company. They noted that the higher up the Key Performance Indicator (KPI) list, the greater the priority to the business. Hinks & McNay identified the top 23 FM KPI's for the financial services sector, noting that the top 10 issues were emphasized by the financial business and the remaining 13 by the facility manager. They also noted the need to understand how the benchmarking results will be used for better resource allocation or FM-unit performance enhancement. With reference to Hinks's suggested key performance indicators, facility managers may design their benchmarking plan and choose measurement criteria based on the following three directions:

   i. Strategy. How well is 'Facility Management' defined within the specific project, and does the chosen benchmarking metrics reflect the strategy of the organization?

   ii. Economic reality and cash flow. How well does the chosen metrics reflect the economic reality that a firm must earn a return on capital invested in excess of its capital cost in order to create financial value?

   iii. Quality of benchmarking metrics. How do relevance and reliability of the performance measures get considered? For example, relevant and reliable FM department's benchmarking metrics are the ones that are sensitive to factors within the control of the department and not sensitive to factors beyond its control.

6) Many functions of facilities, like janitorial, security, trash removal and recycling, are frequently outsourced to specialists who often are relatively small companies with little or no benchmarking experience. Collection of relevant data from these services providers may be a problem.

7) Limitations of financial ratios conventionally used in benchmarking projects other than FM explain the needs for a different benchmarking program for FM: Direct and exclusive application of financial ratios cannot benchmark the whole picture of FM due to differences in scales of facilities, diversification of operations, accounting principles used, different year-ends, etc. Industry averages as benchmarks may not be reliable, i.e. not representative samples. There may be too many ways or variations of calculations (Rees (1999)), and financial statements contain estimates that might distort results. Most importantly, ratios are only financial measures and do not provide a balanced view of performance. One solution is to choose some appropriate ratios for FM benchmarking or to apply a benchmarking tool like Data Envelopment Analysis (DEA).

Financial indicators such as Return of Investment, Profit and Loss can only reflect past performance from the perspective of accounting practice. These figures hardly serve as FM benchmarks for implementation.

Based on Camp (1989)'s work, the rationale for FM benchmarking is illustrated in the following table:

Table 2.1 Rationale for FM Benchmarking

Objective	**Without benchmarking**	**By benchmarking**
Change management or adjust FM strategy	● Evolutionary, risky change with unpredictable outcomes	● Decisions based on proven practices with track records

Identify best practice in FM	● Few solutions from one's management group ● Aggressive catch-up activity	● Options available from benchmarking groups ● Superior performance
Decide customer requirement or appropriate service level	● Based on one's own history or 'good' subjective intuition	● Market reality
Establish goals	● Lacking external focus	● Reliable, achievable
Develop metrics	● Bias is common, market development is usually ignored. ● Strengths and weakness not assessed ● Path with least internal resistance	● Generally accepted ● Achievable & reasonable outputs

2.3.1 Identification of Attributes for FM Benchmarking

To identify the best FM practice companies and to gather benchmarking information about their performances and practices, appropriate types of data in suitable amounts should be collected. Self analysis is an essential step to effective benchmarking. One of the fundamental rules of benchmarking is to know one's own FM practices before attempting to understand the same of peers.

Without a thorough 'inventory' of one's own internal FM products and processes, one may not realize the extent of self-improvement opportunities and potential gap(s). The absence of a thorough internal analysis may lead one to bypass some important internal benchmarking opportunities.

To identify attributes for FM benchmarking, facility manager should review the information already available on FM practice. These may include:

1. Flow charts - this involves taking the FM process to be analyzed and drawing up a diagram to show each step in the process. This is useful for understanding the

process and its drivers.

2. Customer feedback - this involves identifying customers and their needs to assess whether the process is performing well or not. Customers can be asked directly or by formal customer surveys. Answers to these questions can give clear indications as to what aspects of the process should receive priority.

3. Measurements of the process, e.g. number or times of visitors or frequencies. Processes vary widely by goals, philosophies, industry, cultures, management plan, and organizational structure. Process measurement is important to process benchmarking. The significance of process measurement and benchmarking can be illustrated by the benchmarking studies of the Mass Transit Railway Corporation (MTRC) in Hong Kong. Based on their benchmarking studies since 1993, MTRC implemented eight different changes in their purchasing process and were able to reduce material supplier cost by 40 percent. They were also able to save $16.5 million by means of alternative sourcing and $6 million by adopting a noise damping wheel for its multiple electrical units. (Powers (1998))

4. Procedure manuals.

Literature sources such as the following can be helpful, especially if the search is on an international basis:

1. Trade and professional associations: These can be useful particularly if potential benchmark partners are likely to come from a particular industry or service sector.

2. Consultants: They may have databases of best practices and best practice organizations. They can also act as an independent third party.

3. Major suppliers of your machinery, process technology, materials: These can be sources of specific information regarding the potential benchmark partners.

4. Major customers.

FM benchmarking attributes are often documented as the terms of service level agreements (SLAs) and key performance indicators (KPIs) in many FM services contracts.

2.3.2 Service Level Agreements (SLAs)

An SLA is an agreement designed to create a common understanding of services, priorities and responsibilities among customers, FM services providers and buyers. Although an SLA is an excellent expectations-managing mechanism, it would still be important to manage the expectations of what can be realistically accomplished.

With reference to N. Karten (2005), the following points about the setting up of SLAs are noted:

1. The value of an agreement is not just in the final product; the process of establishing an SLA enables communications. It also helps to avoid disputes by providing a shared understanding of the needs and priorities. When conflicts do occur, SLAs can be a base for resolution.

2. SLAs should be flexible as required by FM practice. It is expected that parties to the SLA may need to review the agreement frequently to assess service adequacy and negotiate adjustments.

3. SLAs should objectively gauge service effectiveness. An SLA ensures that FM service buyers and providers use the same criteria to evaluate service quality.

2.3.3 Key Performance Indicators (KPIs)

FM Performance Indicators are measures of FM performance or progress towards objectives of an organization. Usually linked with strategies of the organization and its FM unit, these measures enable the organization and its external stakeholders (customers, funding providers and suppliers) to understand what its goals are and how well it is achieving those goals.

FM KPIs are measures of the overall performance of the FM units, and tend to be kept to a handful of measures. They provide a balanced, unambiguous view of the overall FM performance in the short and long terms. Traditional FM indicators tended to be financial, quantitative and about operations, and are reported through budgets and annual reports. Presently, FM organizations are now measuring more other activities, in order to provide a balance of tangible and intangible FM characteristics and to measure future capability as well as past performance.

2.3.4 Measurement of FM Performance

FM performance measurement, as a stage of FM benchmarking, is critical to the success of FM benchmarking. As noted by Valence (2003), FM performance measurement in the process of benchmarking should show the following characteristics:

1) The general focus is on the relative levels of performance rather than absolute levels.
2) It should involve identification of best practice.
3) The measurements taken should be dynamic (e.g. customers’ feedback) and revised regularly.
4) It should relate to organizational change or the continuous improvement of activities.

A clear SLA with carefully selected KPIs helps accurate measurement of FM performance. SLAs and KPI specifications for FM services based on benchmarking study have been recommended but effectiveness of their application has received little attention (Price 2003). Hinks and McNay (1999) stated some characteristics of representative FM KPIs which are also applicable to planning FM benchmarking:

1. Clearly expressed;
2. Consistent with strategic intent;
3. Reflective of what the FM units are to achieve in order to be successful;
4. Representative of the work that facility managers do;
5. Measured on the basis of what counts (not just what can be counted!);
6. Capable of fully reflecting the stated goals;
7. Can reference current and future customer expectations;
8. Communicated to all stakeholders;
9. Qualitative as well as quantitative.

2.4 Definition of FM Benchmarking

The duties of facility managers include management of maintenance, space management and accommodation standards, project management for newly-built facilities and alterations, the general premises management of the building stock of the company and the administration of associated support services (Hinks and McNay (1999)). Measurement of these diversified duties is complicated and can be costly. A good plan is required before the measurement is carried out.

Benchmarking FM should:

1. Be systematic and well-planned process.
2. Have an external focus on internal activities, functions and operations.
3. Is largely a measurement technique used to compare certain quantitative and qualitative aspects of organizations?

In the arena of FM, as defined in this study, benchmarking should be a continuous and systematic means of measuring and comparing the work processes of an organization by bringing an external focus on internal FM activities, functions and operations.

FM has previously been defined as the service related to the built environment to ensure occupants and their business a pleasant environment, under which commercial occupants can concentrate their resources on their core business and residential occupants can enjoy their living space. To achieve this objective, Facility Managers *"should integrate multi-disciplinary activities, e.g. business administration, architecture, and behavioral and engineering sciences, with the built environment and the management of their impact upon people and the workplace"* (BIFM (2004)).

2.5 Some misconceptions about FM Benchmarking

Benchmarking is not a one-off activity. It is a continuous process whereby an organization seeks continuous improvement through the identification of good practice. Typical FM performance indicators include flexibility (accommodating growth/ shrinkage), provision of a safe environment, effective utilization of space (spatial needs, churn rate, etc.), maintenance. Nevertheless, the perception of FM benchmarking is frequently linked to downsizing or reducing resources rather than related to redeployment of resources for better results.

Facility Manager must be aware that benchmarking is neither a quick fix (usually lasting 9 to 12 months) (Lincoln & Price (1996)); nor is it a simple comparison of one organization to another. Facility managers can thus avoid getting distracted from the objective of benchmarking and will be in a better position to maintain focus and progress toward the ultimate goal, which is matching or beating the best (Keehley & MacBride (1997)).

2.6 Conventional Benchmarking Methodologies

Benchmarking handbooks often offer checklists or flowcharts for the conduct of benchmarking. These checklists are often vaguely defined, e.g. Figure 2.1. Some confusion are noted and listed below:

1. In Camp's benchmarking process, steps one and two are only viable for internal benchmarking. For external benchmarking the projects may involve two or more peers within the benchmarking group. Each would have different expectations or objectives from the project. However, it is argued that it would be too ambitious to assume one can decide what to benchmark and then invite the benchmarking peers. Market reality seems to be ignored or simplified.

2. A similar problem may be noted in Watson's proposed process (Watson (1992)). It is hard to understand how the two phases, planning and searching, can be separated if we are to assume that every member in the benchmarking group is equal. In most cases, after an appropriate number of peers sign a memorandum of understanding, all the members should be involved in the planning process. Watson might have assumed the project was led by a benchmarking consultant who can persuade all potential members to accept his proposal which includes benchmarking objectives, subjects and criteria. During the author's tenure in the Committee of Quality Building Award, it was found that the time involved to persuade benchmarking participants to come to consensus was often underestimated.

3. In an ideal case, observation should precede analysis. Practically, when analysis comes up with some obstacles, more observations such as site visits, interviews or revision of questionnaires are required.

It is rare that benchmarking can be carried out from through all steps as smoothly as shown in Fig.2.1a. This is especially true for large benchmarking groups. Therefore, it is more prudent and practical to have a flexible benchmarking program.

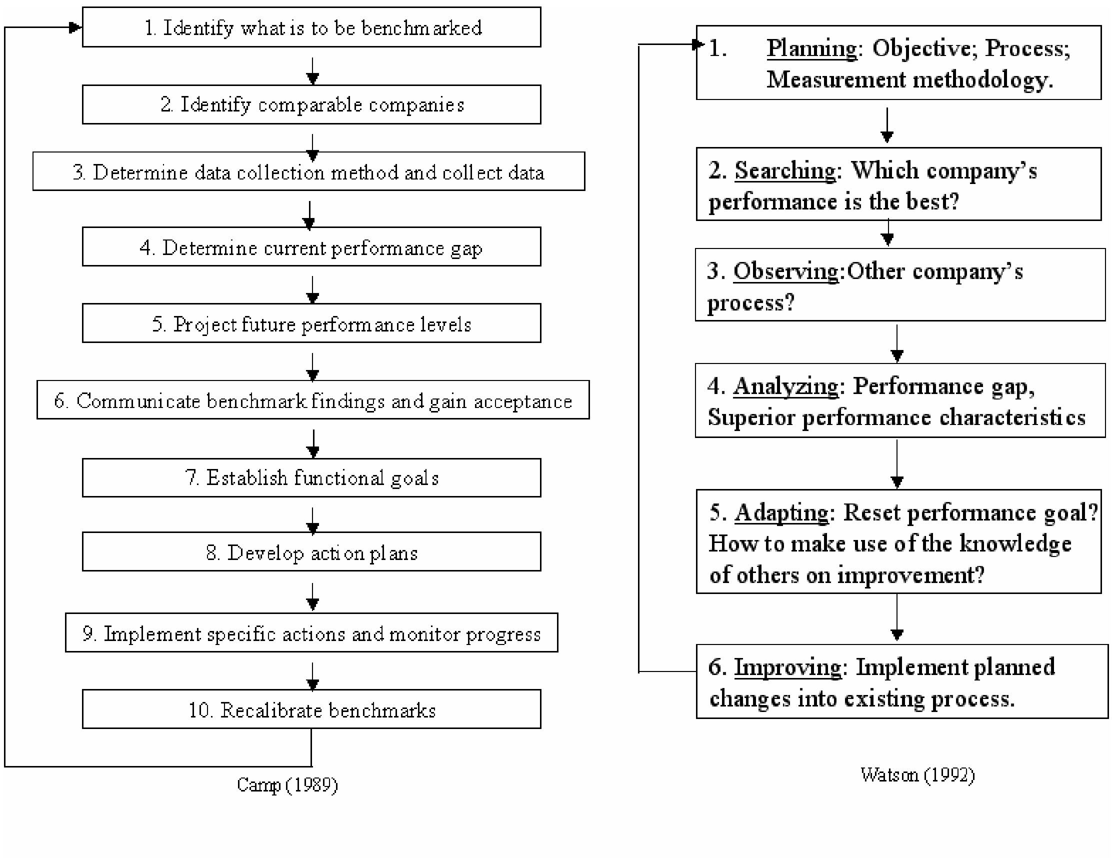

Fig. 2.1a & b   Benchmarking Process: Camp (1989) and Watson (1992)

Codling (1998) synthesized and rearranged different checklists or flowcharts into a benchmarking program and this is found to be a good attempt:

1. Planning
    - Select the subject area
    - Define the process
    - Identify potential partners
    - Identify data sources and select appropriate collection method
2. Collect data and select partners
    - Collect data and select partners
    - Determine the gap compared to benchmark

- Establish process differences
- Target future performance

3. Action

- Communicate to management and others
- Adjust goals and develop an improvement plan
- Implement

4. Review

- Review progress and calibrate

IFMA has its proposed flowchart, Fig 2.2. Similar to those by Camp and Watson, it underestimates the difficulties of data collection and 'politics' within benchmarking group. In most case, simple benchmarking flowcharts can only serve as a reference for facility managers in the early planning stage.

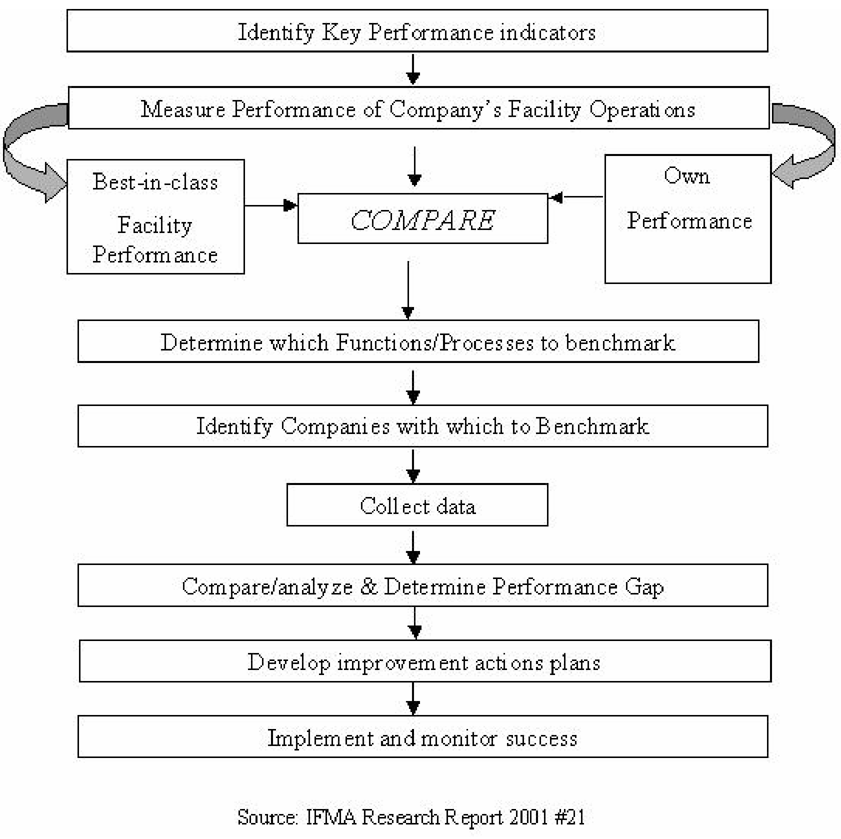

Fig 2.2 Benchmarking Methodology for FM (IFMA, 2001)

To adapt IFMA's flowchart with Codling (1998)'s program, five stages are proposed below.

1. Planning

    - Select the subject area: Consider the characteristics of FM, both soft and hard subjects (to be discussed in a later chapter).
    - Define the process subject to data sources and benchmarking tool(s) to be applied.
    - Identify potential partners and consultants.
    - Identify data sources (e.g. input, output or process) and select appropriate collection method(s).

2. Collect data and select partners

    - Collect data and select partners.
    - Determine metrics of measurement and the gap compared to benchmark.
    - Establish process differences.
    - Target future performance.

3. Action

    - Communicate to operation staff, contractors, management and the executive.
    - Adjust goals and develop improvement plan.
    - Implement and monitor.

4. Review

    - Review progress and calibrate.

Akin to benchmarking, no definition of FM has been universally accepted but the data and information collected for FM benchmarking usually includes:

1. People satisfaction, procedure of solving complaints, comfort,

cleanliness, energy awareness, workers production and absenteeism – soft subjects.

2. Cost of equipment, energy cost per area, indoor air quality – hard subjects.

All these soft and hard subjects call for a multidimensional benchmarking system. Due to the complicated nature of FM, gathering and disseminating a large amount of different information and data is required. Considering the speed and flexibility of information and data systems, it is obvious that information technology (IT) can be very useful for developing in FM benchmarking. Facility managers have been using IT in benchmarking but applications focus mainly on data processing, as elaborated by Hoots (2003). Based on the experience of benchmarking in comparable industries, wider and deeper applications should be encouraged in FM benchmarking especially on the works of analysis at the stage of planning; data collection and partner selection. At the planning stage of a benchmarking project, the American Productivity and Quality Center suggests benchmarking peers have options of data collection. The options are important in attracting more participants to suit their needs and accommodate their constraints. Participants have different learning objectives. The information from benchmarking projects may be used by different departments of participating company. They may have different constraints in search data and information collection. Two mathematical tools – Analytic Hierarchy Process (AHP) and Data Envelopment Analysis (DEA) – are proposed in this thesis to form an FM benchmarking framework to accommodate the required flexibility.

It is noted that there are three basic steps in any FM benchmarking project:

1. Choose the parameter that is important.
2. Look it up or calculate it if necessary.
3. Interpret it and gain some insight into the company.

Parameter means any measure that tells you something about the FM performance. In general, most useful parameters are ratios of one item in the accounts to another.

2.7 FM Benchmarking: Innovation and Continuous Improvements

Innovation is different from continuous improvements since it is not a part of routine operations. It usually requires significant investment of resources and may require changes in operation design. Therefore, innovation and continuous improvements are often investigated separately. Benchmarking study is considered more affiliated with continuous improvements and, sometimes, corrective actions. Based on Imai (1986), it is submitted that benchmarking is very similar to *kaizen* (a Japanese word with the meaning of ‘change for the better’). Both emphasize continuous improvement activities. Adapted from Imai’s works, comparisons are made between innovation and continuous improvements through benchmarking, and are illustrated in Figure 2.2.

As an output of Total Quality Management (TQM), the FM business seems naturally linked more with continuous improvements through benchmarking. The following features of FM explain why benchmarking is a suitable improvement tool for the industry:

1) As a supporting arm to the core business, FM business seldom bears high business risk nor given a generous budget.

2) FM departments of many commercial organizations are responsible for maintenance and property management.

3) Substantial FM costs are security, cleansing and maintenance. They are relatively labour intensive. Technological breakthroughs are difficult.

Table 2.2 Differences between Innovation and Continuous Improvement through Benchmarking

	Continuous Improvement through Benchmarking	Innovation
Existing Process	Little Change	Redesigned
Improvement expected	Modest	Substantial
Change Driver	Everybody	Senior management
Business Risk	Small	High
Capital Expenditure	Small	Substantial
Mode	Maintenance and improvement	Scrap and rebuild
Trigger	Conventional know-how and state of the art	Technological breakthroughs, new inventions and new theories
Effort orientation	People	Technology
Common Evaluation Criteria	Process and efforts for better results	Profits or other financial criteria
Advantage	Works well in slow-growth economy	Better suited to the fast-growth economy

Chapter 3 A Framework for Facility Management Benchmarking

Quality and quantity of FM services are never labelled with a price tag or with full description. A Facility Manager's challenge today is to provide quality services at a reasonable cost instead of quality at an unknown cost.

Badiru and Ayeni (1993) identified benchmarking as a systematic approach to achieve target service level within the constraints of time and resources. They also clearly defined and showed performance measurement and improvement of general operation process from a statistical perspective. But a clear guidance on target setting for improvement execution for benchmarking study was not examined. In this chapter, a FM benchmarking framework with guidance for improvement is proposed.

As a starting point for conducting a benchmarking study, facility managers should have a plan which includes answers to the following questions:

1. What are the relationships amongst the various FM KPI offering insights into the different aspects of the organization's core business? Examples of such include expenditures on refurbishment per square meter of Gross Floor Area (GFA), GFA per Effective Full Time Employee and Maintenance Expenditure per Effective

Full Time Employee. In a discussion on a benchmarking tool, AHP, Cheng *et al*. (2002) investigated the importance of the inter-relationships amongst the KPIs. Cheng illustrated that the wrong conclusions would be drawn if there had been a misunderstanding on KPI when applying the AHP. The same misunderstanding will also adversely affect a benchmarking study even if AHP is not applied. For example, when considering FM cost of a university's lecture theater facilities, facility managers should not consider distance learning students as being part of the end users. However if considering facilities related to the library, especially during the holidays, FM cost should be considered.

2. What are the criteria or determinants in the process of FM operation or procurement? There were some opinions from FM practitioners at the CIB conference (W70 working commission) held in December 2004 and organized by The Hong Kong Polytechnic University saying conventional benchmarking flow and checklist were found to be too general as guidance for FM benchmarking. With reference to Watson (1992), the opinions at the conference were respectfully disagreed: benchmarking flow and checklists are often general because they must be flexible and applicable for most industries. To apply benchmarking tools in conventional benchmarking guidebooks, facility managers should decide the FM criteria for their organizations. Some typical performance measurement in general benchmarking handbooks, like product cycle time, and product features should be replaced by comparables in FM field, e.g. service cycle time or response time and lessee features or composition in the building.

3. In the selection of benchmarking partners, are the operating sequences and the range of benchmarked items comparable? With reference to a large-scale benchmarking study on public transport in Europe by The University of Newcastle upon Tyne (2000) - EQUIP, the selection of benchmarking partners started after confirmation of KPI, comparison of the centralized database and identification of areas for improvement. The selection may be made in reference to the following:

a) Scale of the operation;

b) Operating characteristics;

c) Internal organisation; and

d) Information systems.

An objective of partner selection is to investigate whether benchmarking partners possess "the best of class" practice in the field.

4. The final question is, as noted by Mertins, Kempf and Siebert (1995), whether it is likely that information about partners' strengths and weaknesses can be identified. Apart from the availability of data, the use of benchmarking tools is critical in identifying partners' strengths and weaknesses. Based on the suggestions of Mertins, Kempf and Siebert, this chapter shows the use of benchmarking tools and how targets for improvement are identified with the relevant tools.

Having identified the above issues, it can be seen that the FM benchmarking process is often perceived to be complicated and difficult to be structured. Therefore, a framework is in demand to turn the unstructured process into an objective action plan for improvement.

3.1 Composition of the Facility Management Benchmarking Framework

Information from FM benchmarking study is commonly used for FM units to:

a) Control and adapt to change;

b) Motivate FM staff and communicate with executives of other departments.

Control and adapt to change

Garratt (1987) has developed a model of the learning organization. Figure 3.1 (with adaptation for FM operation) illustrates that information is needed for operations control (control of the daily activities of an organization) and for policy adaptation (reacting to changes in the external environment).

Applying the learning process as a part of benchmarking, facility managers should process and integrate the information obtained from operation and policy formulation to develop FM strategies, give direction and monitor the results. Nutt (2000) considered, in a discussion of FM definition, that FM knowledge has three origins – property, general management and facilities design. These three critical issues can further expand to strategic knowledge which links to life-cycle design and management. This is a reflective process premised on the need to minimize costs through an understanding of productivity and by exploring opportunities through a full and accurate knowledge of building performance. Nutt further elaborates by identifying other FM issues such as the management of financial, physical and human resources in FM. A structure is required to arrange these diversified information before a comparison can be made possible.

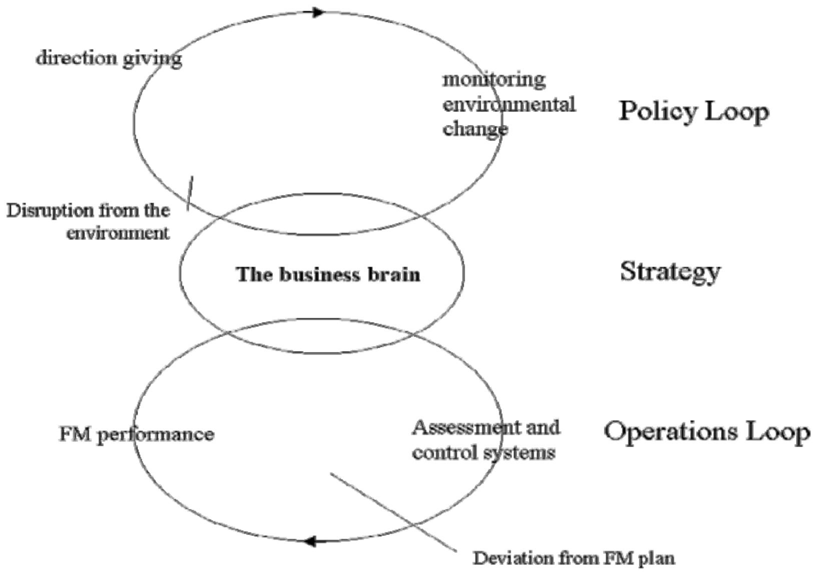

Figure 3.1 Strategy formation: Interaction of policy and operation, adapted from Garratt (1987)

Having recognized that information and data processing is an important part of FM operations, Anthony and Young (1984) pointed out how information should be processed and reported: Accounting information, along with a summary of FM data, is summarized, analyzed and reported to those who are responsible for knowing the FM process in the organization and who are charged with attaining the agreed-upon levels of performance and services. These reports are then used to compare planned inputs and outputs with actual inputs and outputs. Based on site visits and meetings with Facility Managers of The University of Hong Kong, The Hong Kong University of Science and Technology and JP Morgan Chase, it is submitted that the FM operation process and its benchmarking may be considered to be consisting of the input, process and output components as shown in Figure 3.2. This submission is further supported by The Hong Kong Institute of Facility Management (HKIFM). HKIFM defined *FM as a process by which an organization integrates its people, work process and physical assets to serve its strategic objectives*. For the purpose of benchmarking, it is argued that FM may be construed as services operation management and the flow of FM information in the form of an input-output system with meters of benchmarking helping FM units to control and adapt to change to the levels of operation, policy and strategy formation.

Motivate FM staff and communicate with executives of other departments

Information from an FM benchmarking study enables FM staff, units and organizations to know how they perform, with a view to influencing practice and decision. Positive feedback serves to clarify goals and by so doing increases the motivation to perform well. Other feedback offers hints for improvement and assessment references.

Conventional FM benchmarking studies emphasize the comparison of FM inputs, outputs and outcomes individually. An example is the benchmarking studies carried out by The Australasian Tertiary Education Facilities Management Association (TEFMA). Since an individual facility manager is only responsible for a part of the FM process, partial comparison of the FM process cannot reflect the scale of FM operation and a facility manager cannot figure out his own improvement target.

A revolutionary type of benchmarking study was developed and started to be implemented in the 1980s. The so-called process benchmarking covers both key input and output items. Efficiencies of the operation units are examined.

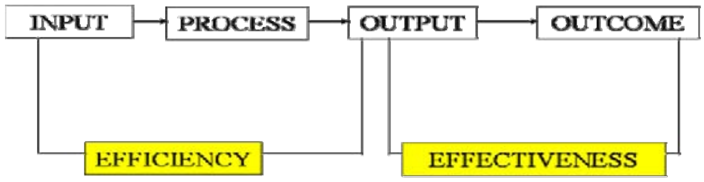

Figure 3.2 FM Information flow and meters of benchmarking

A process benchmarking study was conducted with participation of mass transit systems from Mexico City, New York City, Paris, London, Moscow, Sao Paulo, Berlin, and Hong Kong through the incorporation of Community of Metros (CoMET). Each year the members gather their respective performance data, which are then compared in semi-annual meetings. Five key areas of interest are service quality, reliability, efficiency, asset utilization, and financial performance. These areas of interest led to the development of eighteen KPIs under five categories, as shown in Table 3.1.

Table 3.1 Process benchmarking by Community of Metros: KPI and the categories

Categories	**Key Performance Indicators (KPI)**
Financial Performance	Total cost/ passenger
	Operations cost/ passenger
	Maintenance cost/ revenue car
	Fare revenue/ passenger
	Total commercial revenue/ operations cost
	Operations cost/ revenue car operating km
	Total cost/ revenue car operating km
Efficiency	Passenger journey/ total staff + contractor hours
	Revenue capacity km/ total staff + contractor hours
	Revenue car km/ total staff hours
Asset Utilization	Passenger km/ capacity km

	Capacity km/ track km
Reliability	Revenue car operating hours between incidents
	Car operating hours/ total hours delay
	Trains on time/ total trains
	Revenue operating car km/ total incidents
Service Quality	Total passenger hours delay/ 1000 passenger journeys
	Passenger journeys on time/ total passenger journeys

It was noted that the chosen KPI successfully benchmarked the operation efficiencies but the operation effectiveness was not considered. It did not measure customers' satisfaction with reference to the operation outputs. From the FM perspective, service quality cannot be represented solely by total passenger hours delay/1000 passenger journeys and passenger journeys on time/ total passenger journeys.

With reference to Figure 3.2, the CoMET benchmarking project examined the picture of operation in terms of efficiency, not effectiveness. Efficiency is measured by the ratio of inputs to outputs, e.g. FM cost per square meter, the gross cost per school pupil. The objective of efficiency measurement is usually to minimize inputs, to maximize outputs, or to do both. Effectiveness is a more complicated concept than efficiency and definitions of it vary considerably. A widely accepted definition is that effectiveness is the degree of success of activities or services in meeting their objectives; in other words, whether the outcomes specified in the objectives are achieved. This raises the question of whose objectives are to be taken into account. In determining effectiveness, it is necessary to specify clearly what stakeholders should be recognized and what their objectives are. Due to its subjective nature, effectiveness is usually interpreted as expectations or perception and measured in terms of relativity.

To take account of the effectiveness and efficiency of FM operation, and their relationships, a systematic benchmarking framework is proposed and illustrated in

Figure 3.3. This is discussed in the rest of this chapter.

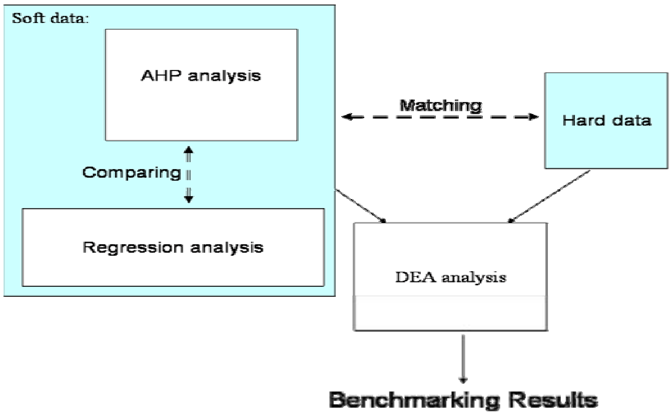

Figure 3.3 Proposed Benchmarking Framework

The proposed framework is a mixed-method approach consisting of intentionally combined evaluation tools and techniques not only to observe and to gather quantitative and qualitative information (hard and soft data), but also to analyze, judge and structure the FM information. Unlike the conventional benchmarking flow, the framework is designed to assist facility managers in organizing the collected data. Both hard and soft data are collected with reference to the benchmarking objective. Based on the case studies to be elaborated in Chapters 4 and 5, it is recognized that facility managers' understanding of their services and customers; and customers' perception on the FM performance should be collected, compared and analyzed in FM benchmarking process for efficiency and effectiveness assessments. Facility managers' understanding and customers' demands should be compared for better resource allocation and focus with reference to the organization objective. For example, if an organization has decided to save FM cost, the facility manager should collect the related hard data (e.g. with reference to ventilation cost, air-conditioning system operation details during and after office hours); and then set targets with an execution plan with reference to safety requirements and customers expectations on comfort level.

The FM benchmarking framework is designed with reference to two concepts:

1. Straub (2002) studied the management of maintenance performance by a client-centred approach and a condition assessment method. Pilot studies were

done by five Dutch housing associations. It was discovered that maintenance performance and costs can be controlled at a desired level with the condition assessment method based on a client-centred approach. Brandon and Ribeiro (1998) demonstrated how a knowledge-based system with a client-centred approach could assess applications for house renovation grants. The system was proved as capable as human experts.

With reference to Brandon and Straub's works, it is argued a that facility manager can satisfy customers' demand for FM service at desired cost with a client-centred approach. Closer examination of customers' demand is then required. In the proposed framework of this study, linear regression is applied to study customer demands for FM services for its simplicity and accuracy.

2. With the examination results of customers' demand, facility managers can then design FM services for their customers with AHP and DEA:

    a. AHP: To evaluate Facility Managers' comprehension of customers' demands with reference to current FM strategy.

    b. DEA: Based on the concept of input-output process, FM operation processes can be assessed on the scale of efficiency and effectiveness.

3.2 Multiple Criteria Decision Model (MCDM)

In order to select the best FM practices in the process of benchmarking, facility managers have to consider (i) some FM objectives which may conflict with one another (e.g. costs verse customer satisfaction); (ii) a variety of persons involved and their views; and (iii) the spatiotemporal distribution of the decision outcomes. This is a common problem in the comparison stage of benchmarking, in which multiple criteria decisions have to be made. The unstructured nature of criteria will influence facility managers' judgment. A multi-criteria decision problem generally involves choosing one of a number alternatives based on how well those alternatives rate against a chosen set of criteria. The criteria themselves are weighted in terms of importance to the decision maker, and the overall "score" of an alternative is the weighted sum of its rating against each criteria. The ordering of the alternatives by their decision scores is considered to be their ranking by preference.

This multiple criteria problem is often beyond the cognitive ability of decision makers. Decision theory may be applied to support dealing with such unstructured decision problems. The formal approach of decision theory, which analyses subjective utility and measures satisfaction achieved by decision alternatives, makes the decision more transparent and consistent (i.e. rational), and allows multiple decision makers and stakeholders responsible for or affected by the decision to communicate their positions and adjust their expectations.

To apply decision theory to the benchmarking problem, an MCDM is built to assist decision-makers in organizing and synthesizing information against a complex and conflicting nature of problems. Wong and Gilleard (2004) demonstrated how an MCDM could be developed with the Analytical Hierarchical Process (AHP) (Saaty (1980)) for a problem of office location selection from FM perspectives. With AHP, Wong and Chan (2003) also showed that MCDM, compared with the conventional marking scheme method, is a better mechanism in the selection of Private Finance Initiative (PFI) bidders in the construction industry. The advantages of MCDM are more obvious, where a large amount of criteria are taken into account simultaneously. In an FM benchmarking problem, these criteria are often related to one another in a complex way and are usually conflicting. Since most of the criteria are of a qualitative nature, decision-makers have to make decisions based on both the quantitative data and subjective judgments.

3.3 Common tools for Multiple Criteria Decision making

In general, when decision makers make multiple criteria decisions, they must address how they will structure the problem, weigh the criteria and score the alternatives. Of these, the choice of tool is the most crucial because it dictates what multiple criteria trade-offs should be made and how a compromise is reached.

Methods commonly associated with attribute, utility and relative measurement is Multi-Attribute Utility Theory (MAUT), Simple Multi-Attribute Rating Technique (SMART) and the Analytical Hierarchy Process (AHP):

I. MAUT is a quantitative comparison method used to combine dissimilar measures of costs, risks, and benefits, along with individual and stakeholder preferences, into high-level, aggregated preferences. The foundation of MAUT is the use of utility functions. Utility functions transform diverse criteria into one common, dimensionless scale (0 to 1) known as the multi-attribute "utility". Once utility functions are created, an alternative's raw data (objective) or the analyst's beliefs (subjective) can be converted into utility scores. The criteria are then weighted according to their importance. To identify the preferred alternative, each normalized alternative's utility score results with respect to each criterion are multiplied with the weight of the criterion before summation is made for each alternative. The preferred alternative will have the highest total score.

   Utility functions are typically used. When quantitative information is known about each alternative, this can result in a firm estimate of the alternatives' performance. Utility graphs are created based on the data for each criterion. Every decision criterion has a utility function created for it. The utility functions transform an alternative's raw score (i.e. dimensioned – feet, pounds, gallons per minute, dollars, etc.) to a dimensionless utility score, between 0 and 1. The total scores also indicate the ranking for the alternatives.

   The MAUT evaluation method is suitable for complex decisions with multiple criteria and many alternatives. Additional alternatives can be readily added to a MAUT analysis, provided that the data are available to determine the utility from the utility graphs. Once the utility functions have been developed, any number of alternatives can be scored against them. For theoretical details, reference may be made to Pratt, Raiffa and Schlaifer (1996).

II. The Simple Multi Attribute Rating Technique (SMART) is a variant of the MAUT method. This method utilizes simple utility relationships. Convenient scale can be applied by data normalization to define the utility functions. Three, four and five point scales are the most commonly used in FM customer satisfaction surveys.

In SMART, ratings of alternatives are assigned directly, with the natural scales of the criteria (where available). For instance, when assessing the criterion "top speed" for motor cars, a natural scale would be a range of 100 to 200 miles per hour. In order to keep the weighting of criteria and rating of alternatives as separate as possible, the different scales of criteria need to be converted into a common internal scale. This is done mathematically by means of a "Value Function". The simplest choice of a value function is a linear function, and in most cases, this is sufficient. An advantage of SMART is that the decision model is independent of the alternatives. While the introduction of value functions somewhat makes the decision modelling process complicated, an arguable advantage is that the ratings of alternatives are not relative, so that changing the number of alternatives considered will not in itself change the decision scores of the original alternatives.

Because of its simplicity of both responses required of the decision maker and the manner in which these responses are analyzed, SMART has been widely applied. The analysis involved is transparent, so the method is likely to yield an enhanced understanding of the problem and can be acceptable to the decision maker.

The stages in the SMART analysis are as follows:

a) Identify the decision maker or makers.

b) Identify the alternative courses of action.

c) Identify the attributes which are relevant to the decision problem.

d) For each attribute, assign values to measure the performance of the alternatives on that attribute.

e) Determine a weight for each attribute.

f) For each alternative, take a weighted average of the values assigned to that alternative.

III. AHP allows users to assess the relative weight of multiple criteria (or multiple alternatives against a given criterion) in an intuitive manner. Its major innovation was the introduction of pair-wise comparisons. Pair-wise comparisons represent a method that is informed by research for showing that when quantitative ratings are unavailable, human beings are still adept at recognizing whether one criteria is more important than another. Saaty, the inventor of the AHP, established a consistent way of converting such "pair-wise" comparisons (X is more important than Y; in the scale of ± 1-9) into a set of numbers representing the relative priority of each criterion and the consistency of comparisons is checked for data validation.

A potential drawback with the AHP method is "Rank Reversal": Because judgments in AHP are relative by nature, changing the set of alternatives may change the decision scores of all of the alternatives. It was shown that even if a very poor new alternative is added to a completed model, relative ranking of the alternatives with the top scores may be reversed.

To decide which tool is more suitable for FM benchmarking, the following observations are submitted:

1. The simplicity and clarity of building an AHP model where both qualitative and quantitative aspects of a decision need to be considered – typical of FM benchmarking – has encouraged its potential application. Nevertheless, if new alternatives are likely to be added to the model after its initial construction and the alternatives are amenable to a direct rating approach (not so qualitative as to require pair-wise comparison), and then MAUT or SMART will be a good choice.

2. Based on the study of Brugha (2003), Multiple Criteria Decision Model (MCDM) may be divided into phases of screening, ordering (Ranking) and choosing MAUT, SMART and AHP can be applied in different phases. Brugha examined the three phases with respect to the number of alternatives to be dealt with, effort required, measurement precision and cognitive sophistication, as summarized in Table 3.2. It is submitted that in the analysis stage of FM benchmarking, most comparison works involved are related to the choice of the best FM practice. It is put forward that AHP is the most suitable analysis tools for comparison, based on the works of Brugha (2003). A summary of the results is given in Table 3.3.

Table 3.2 Phases of Multi-criteria preference finding and their requirements

Phase	Alternatives	Effort required	Measurement precision required	Cognitive sophistication required
Screening	Many	Low	Low	Low
Ordering / Ranking	Any	Medium	Medium	Medium
Choosing	Few	High	High	High

Source: Brugha (2003)

Table 3.3 Suitability of methods to phases of MCDM

Methods	Most suited to Phases	Suitable for alternative	Type of measure	Effort required	Quality of measurement Function	Cognitive sophistication
SMART	Screening	Many	Attribute	Low	Low	Low
MAUT	Ordering/ Ranking	Interim	Utility	Medium	Adequate	Medium
AHP	Choosing	Few	Relative	High	Low	High

Source: Brugha (2003)

Screening is not generally done in the analysis stage of benchmarking if good planning was done from the outset. Unnecessary data or information should have been screened at the planning stage. Ordering/ranking and the application of MAUT are only common for performance measurement and internal assessment based on quantitative information. After identifying the AHP method as an analysis tool for FM benchmarking, investigation of its application along with other tools is described below.

3.4 Analytic Hierarchy Process (AHP): Analyzing soft aspects of FM Performance

The AHP is a mathematical decision making technique that allows consideration of both qualitative and quantitative aspects of decisions. It reduces complex decisions to a series of one-on-one comparisons (pair-wise comparison), then synthesizes the results.

Compared to other techniques like those mentioned above, AHP uses the human ability to compare single properties of alternatives. It not only helps decision makers choose the best alternative, but also provides a clear rationale for the choice. The process was developed in the 1970s by Thomas Saaty, then a professor at the Wharton School.

AHP application consists of four major steps:

1. Modelling the decision problem by breaking it down into hierarchy of interrelated decision elements and alternatives;

2. Developing judgmental preferences (called preference matrices) of decision alternatives for each criterion and judgmental importance of the decision criteria by pair-wise comparisons;

3. Computing relative priorities for each of the decision elements, through a set of numerical calculations, called matrix normalization procedure; and

4. Aggregating the relative priorities to arrive at a priority ranking of the decision alternatives, achieved by computing the eigenvectors of the matrices.

"AHP is a powerful and flexible decision-making process developed to set priorities

and make the best decision when both qualitative and quantitative aspects of a decision need to be considered. By reducing complex decisions to a series of pair-wise comparisons, and then synthesizing the results, AHP not only helps decision-makers arrive at the best decision, but also provides a clear rationale for the decision" (Expert Choice, 2002).

In the examination of facilities management performance assessment, Hinks and McNay (1999) stressed the importance of criteria ranking in resources allocation. That may explain why benchmarking results are usually referred to in the allocation of resources or planning of the FM budget. As qualitative information and quantitative data are often involved, Gilleard and Wong (2004) proposed AHP as a tool for criteria ranking. Gilleard and Wong identified three contribution of AHP in the process of FM benchmarking: ranking criteria, establishing consensual data input and sensitivity analysis.

Based on the text by Winston (1994), Wong and Chan (2003) illustrated the application of AHP with information drawn from the Marine Department, Hong Kong SAR Government for procurement of vessels. The illustration is summarized below to demonstrate AHP application.

In determining which tender to accept, the Marine Department picked among the submitted tenders by assessing how well each tender meets the following criteria:

1. Tender price [denoted by P]
2. Staff experience [denoted by S]
3. Equipment [denoted by E]
4. Company organization [denoted by C]

Pair-wise comparisons among the four criteria are made on an integer-valued scale of 1-9:

Table 3.4 Description of the 1-9 scale of AHP

Value of a_{ij}	**Interpretation**
1	Criteria i and j are of equal importance.
3	Criterion i is moderately more important than Criterion j.
5	Criterion i is strongly more important than Criterion j.
7	Criterion i is very strongly or demonstrably more important than Criterion j.
9	Criterion i is extremely more important than Criterion j.
(2, 4,6, 8)	(Respective intermediate values)

(Source: Saaty (1980))

The six pair-wise comparison values are presented in the following matrix: For example, the importance of price in the tender selection is 5 times that of staff experience.

	P	S	E	C
P	1.0000	4.0000	3.0000	4.0000
S	0.2500	1.0000	0.5000	0.3333
E	0.3333	2.0000	1.0000	3.0000
C	0.2500	3.0000	0.3333	1.0000

For the time being, it is assumed that the above comparisons are completely consistent at this stage. Next, to find the relative weights among the 4 criteria, assume W = [w_1 w_2 w_3 w_4].

Consider the system of n equations: $A\mathbf{w}^T = \Delta\mathbf{w}^T$ where Δ is an unknown number; A is the pair-wise comparison matrix of a perfectly consistent decision maker and $\mathbf{w}^T$ is an unknown n-dimensional column vector. It can be shown that if we do not allow $\Delta = 0$ and A is in the form of

w_1/w_1	w_1/w_2	. . .	W_1/w_n
w_2/w_1	w_2/w_2	. . .	w_2/w_n
. . .	. . .		. . .
w_n/w_1	w_n/w_2	. . .	w_n/w_n

(i.e. A is the pair-wise comparison matrix of a perfectly consistent decision-maker)

then the only non-trivial solution to $A\mathbf{w}^T = \Delta\mathbf{w}^T$ is $\Delta = n$ and $\mathbf{w} = [\ w_1\ w_2\ w_3 \ldots w_n\ ]$.

This shows that for a perfectly consistent decision maker, the relative weights among the criteria, i.e. W, can be obtained from the only non-trivial solution to $A\mathbf{w}^T = \Delta\mathbf{w}^T$. In most situations in reality, where not all of these pair-wise comparisons are consistent, Saaty (1980) has proved if the pair-wise comparisons do not deviate much from perfect consistency, we would expect Δ_{max} to be close to n and $\mathbf{w}_{max}$ to be close to $\mathbf{w}$, where Δ_{max} be the largest number for which $A\mathbf{w}^T = \Delta\mathbf{w}^T$ still holds and has a nontrivial solution: $A\mathbf{w}^T = \Delta_{max}\mathbf{w}_{max}{}^T$. Saaty's works also showed that by taking the difference between Δ_{max} and n, the consistency of the comparisons can be verified.

The rest of the work to be done includes:

a) To normalize the pair-wise comparison, A:

	P	S	E	C
P	0.5455	0.4000	0.6207	0.4800
S	0.1364	0.1000	0.1034	0.0400
E	0.1818	0.2000	0.2069	0.3600
C	0.1364	0.3000	0.0690	0.1200

b) To average the values in each row of the normalized matrix to obtain the relative weight among the 4 criteria:

$w_1 = (0.5455 + 0.4000 + 0.6207 + 0.4800) / 4 = 0.5115$

$w_2 = (0.1364 + 0.1000 + 0.1034 + 0.0400) / 4 = 0.0950$

$w_3 = (0.1818 + 0.2000 + 0.2069 + 0.3600) / 4 = 0.2372$

$w_4 = (0.1364 + 0.3000 + 0.0690 + 0.1200) / 4 = 0.1563$

c) Similarly, the relative weight among the tenders with respect to each criterion can be obtained by the same procedure as stated above. Results are listed below:

1) With respect to the criterion of Price, the scores of tenders 1, 2 and 3 are 0.5949, 0.2766 and 0.1285 respectively.

2) With respect to the criterion of staff experience, the respective scores of tenders 1, 2 and 3 are 0.1335, 0.2114 and 0.6551.

3) Regarding equipment, the respective scores are 0.0934, 0.6853 and 0.2213.

4) Regarding company organization, the scores are 0.0819, 0.3431 and 0.5750.

d) The weighted average rating for each tender is then evaluated by

1) Multiplying the weight of each criterion to the weight of each tender with respect to the respective criterion;

2) Summing up the products for each tender. The one with the highest score is the best of the breed.

Tender 1 score = 0. 5949 x 0.5115 + 0.1335 x 0.0950 + 0.0934 x 0.2372 + 0.0819 x 0.1563 = 0.3519

Tender 2 score = 0. 2766 x 0.5115 + 0.2114 x 0.0950 + 0.6853 x 0.2372 + 0.3431 x 0.1563 = 0.3777

Tender 3 score = 0. 1285 x 0.5115 + 0.6551 x 0.0950 + 0.2213 x 0.2372 + 0.5750 x 0.1563 = 0.2703

Therefore Tender 2 is the most favourable.

e) Finally, the consistency is checked.

What we have shown above is the simplest application of AHP. The structure of the AHP process in the example may be illustrated in Figure 3.4. Details of the mathematical treatment and proof can be found in the publication of Saaty (1980). Various generations and software of AHP have been developed to suit different scenarios of application. We propose the application of AHP in FM benchmarking because it is better than the commonly used Likert Type Rating Scale method for data collection and then processed by SMART, in providing more consistency. Instead of ranking or rating all alternatives with respect to a criterion at one stage, AHP breaks down the comparison process in n (n-1)/2 pair-wise comparisons where n is the number of alternatives. In so doing, the consistency can be easily checked. For the above example, it is noted that the pair-wise comparison of importance between Price and Equipment is three. We also noted that Equipment is twice as important as Staff Experience. Consistency of importance would imply that Price should be six times

(3x2) as important to Staff Experience. However, four is put in for the AHP evaluation. AHP provides a more straightforward test on consistency and establishes the values of Random Index for the checking of any serious inconsistencies.

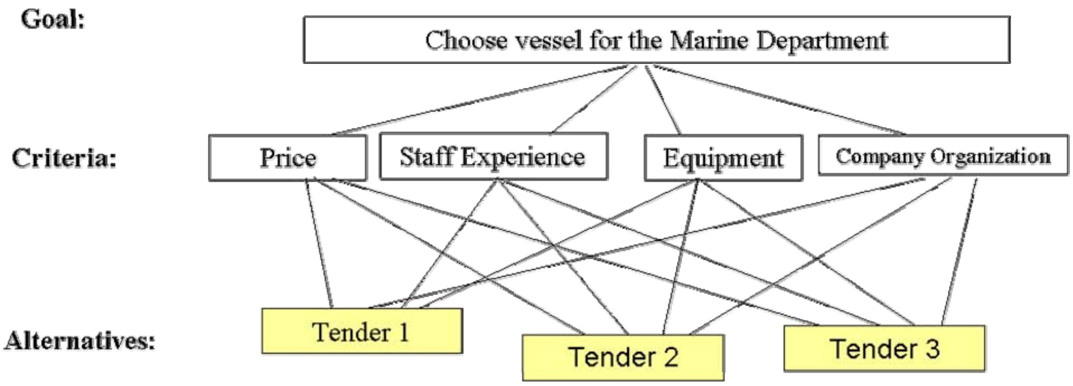

Figure 3.4 AHP Structure

AHP brings flexibility to the benchmarking process due to the perspectives below.

a) Due to its unique structure, modification of criteria or sub-criteria under an existing structure does not influence the pair-wise comparisons under other criteria. The ease of adjustment on AHP structure facilitates consultation in group decision making. Confirmation of benchmarking partners is suggested after an initial selection process of criteria is completed.

b) With AHP software, sophisticated sensitivity analysis can show how the priorities of alternatives change when the weights of criteria change.

c) Generally AHP distinguishes itself from other decision tools by setting up a well-structured hierarchy, as shown in Figure 3.4. By applying AHP, three general types of human judgments, namely importance, preference and likelihood, can be rated systematically.

d) It is convenient for data processing if a survey is conducted on the internet and participants can get the whole picture of the hierarchy before taking part in the survey.

The above advantages allow facility managers to apply AHP and benchmarking results as an expert system in the process of FM planning. For example, it is recognized that expenditure on electricity will be uncertain, so facility managers can adjust the FM inputs proportion (e.g. cleaning cost, maintenance fee, energy use and security cost) in the budget with AHP according to latest electricity price forecasts and other relevant information. The benchmark and guideline of electricity use may be reviewed with the proposed FM benchmarking framework. With reference to Garratt (1987), as discussed in Para. 3.1, AHP can be applied to integrate FM information from the levels of policy formation and operation to the FM strategic level.

Disadvantages of AHP are:

1. The survey by means of AHP takes a long time to complete.
2. Training of surveyors and explanations to survey participants may be tedious.

Therefore, in our proposed framework [Figure 3.3, page 46], AHP will only apply to the analysis of qualitative data from the executives or facility managers, i.e. facility managers' comprehension of their customers' demand for FM services. The Delphi method is suggested with AHP analysis if a group decision is to be made.

Ahsan (2004) demonstrated how Delphi method and AHP can be applied to implement healthcare performance analysis. The outcome of Delphi is used as input for the hierarchical processing procedure in AHP and determines performance order of the healthcare activities. Results from AHP are discussed for implementation in decision-making and the managerial policymaking process, towards improvement of overall healthcare performance.

AHP is not suggested for large-scale customers' survey for survey consistency. AHP

allows more accurate judgements than the simple weighted product model because it evaluates decision alternatives by pair wise comparison (Saaty, 1994). AHP analysis is plausible only if the comparison matrices are consistent or near consistent. Especially for high order matrices, consistency is difficult to reach if the alternatives can only be measured on an ordinal scale. To improve an inconsistent matrix, a user can be asked to reconsider pair wise comparisons until the consistency measure proves to be satisfactory (e.g. Harker, 1997). Feedback after the completion of the comparison matrix is frustrating to the user, because it gives no hints about the comparisons to reconsider.

Some recent developments and critiques on AHP applications and MCDM in benchmarking are summarized below:

1. AHP is not just a methodology for choices. Foreman and Gass (2001) noted three major functions of AHP: (1) structuring complexity; (2) measuring on a ratio scale and (3) synthesizing. The three functions improve the flexibility of FM benchmarking: each benchmarking partner, after obtaining data and information on others, can design his own improvement implementation plan with AHP. He may adjust the comparison structure to fit his FM strategy, e.g. by incorporating different weights of criteria. They can carry out their own customer satisfaction survey and fit in with other data as desired, for forecasting purpose. For example, upon the existing AHP structure of Figure 3.4, an additional criterion of customer services quality may be incorporated.
2. Xerox is not only the first practitioner of modern benchmarking but also an AHP user. It has applied AHP in over 50 major decision situations (Expert Choice, 2002). These include R&D decisions, technology implementation, customer requirement structuring, etc.

3.5 Regression: Analyzing soft aspects of Facility Management Performance

Regression analysis models the relationship between one or more response variables (also called dependent variables; usually named Y), and the predictors (also called independent variables; usually named X1,...,Xp). Multivariate regression describes models that have more than one response variable.

The most popular types of regression are simple and multiple linear regressions.

Simple linear regression and multiple linear regression are related statistical methods for modelling the relationship between two or more random variables using a linear equation. Simple linear regression refers to a regression on two variables while multiple regression refers to a regression on more than two variables. Linear regression assumes the best estimate of the response is a linear function of some parameters (though not necessarily linear on the predictors).

Nonlinear regression models are also commonly applied. If the relationship between the variables being analyzed is not linear in parameters, a number of nonlinear regression techniques may be used to obtain a more accurate regression.

Although these three types are the most common, there also exist Poisson regression, supervised learning, and unit-weighted regression.

Linear regression is investigated in this research. It is applied for building statistical models that characterize relationships between a dependent variable and one or more independent variables, all of which are numerical. The two broad categories of regression analysis are:

a) Regression models of cross-sectional data;

b) Regression models of a time series, in which the independent variables are time or some functions of time and the focus is on predicting the future.

Regression analysis in the benchmarking framework is applied to investigate the relative importance of individual FM services in the customer perception of the overall level of FM service. The relative importance can then be used as the weights of inputs and outputs for DEA calculations and be compared with facility manager's comprehension on the relative importance derived from the AHP analysis. It is submitted that the DEA calculations with a weight-setting mechanism can show a better picture of customers' demand. The comparison with facility manager's comprehension can improve the supply focus on key FM services.

In the analysis of FM Performance, a main subject is customers' satisfaction.

Therefore, the discussion below will concentrate on regression models of cross-sectional data, i.e. customers' overall satisfaction on FM services and their satisfaction on individual FM items.

The goal of regression analysis is to determine the values of parameters for a function that cause the function to best fit a set of data observations. In linear regression, the function is a straight-line equation. For example, if we assume the customer satisfaction of overall FM services is the sum of the satisfaction values of the other FM items, the following linear function would predict the value of the general customer satisfaction (the dependent variable on the left side of the equal sign) as a function of the 6 independent variables. Regression analysis will determine the best values of the 6 parameters (W_1, W_2 … W_6). A data file containing the values of the dependent and independent variables for a set of observations must be provided. In this example each observation data record would contain 7 numbers: The customer satisfaction on Security Comfort Level, Attitude of Guard, Cleanliness of Common Areas, Cleanliness of Office Areas, Cleanliness of Pantry, Cleanliness of Washrooms and Overall Satisfaction.

Overall Satisfaction = Security Comfort Level (W_1) + Attitude of Guard (W_2) + Cleanliness of Common Areas (W_3) + Cleanliness of Office Areas (W_4) + Cleanliness of Pantry (W_5) + Cleanliness of Washroom (W_6)

where W_1, W_2 … W_6 are respective relative weights of customer satisfaction on Security Comfort Level, Attitude of Guard, …

Once the values of the parameters are determined, the formula can be used to predict the customers' overall satisfaction with the 6 predicted variables. If a perfect fit existed between the function and the actual data, the actual value of customers' satisfaction in the data file would exactly equal the predicted value. However, this is typically not the case, and the difference between the actual value of the dependent variable and its predicted value for a particular observation is the error of the estimate which is known as the "deviation" or "residual". The goal of regression analysis is to determine the values of the parameters that minimize the sum of the squared residual values for the set of observations. This is known as a "least squares" regression fit. The more observations one has, the more accurate will be the estimate of the parameters.

The common regression analyses include multivariate, linear, polynomial, exponential, logistic, and general nonlinear regression. It means that the form of the function to be fitted to the data needs to be specified and the function may include nonlinear terms. An example of nonlinear regression is a depreciation problem. The value of a used airplane decreases each year with its age. Assuming the value of a plane falls by the same amount each year, a linear function relating value to age is:

$$Value = p_0 + p_1*Age$$

p_0 and p_1 are the parameters whose values are to be determined. However, it is a well-known fact that planes (and automobiles) lose more value during the first year than in the second, and subsequent years. This means that a linear (straight-line) function cannot accurately model the real situation. Hence, a better, nonlinear, function is established:

$$Value = p_0 + p_1*\exp(-p_2*Age)$$

Where the "exp" function is the value of e (2.7182818...) raised to a power. This type of function is known as "negative exponential" and is appropriate for modelling a value whose rate of decrease is proportional to the difference between the value and some base value.

In dealing with customer satisfaction or other soft data, some researchers suggested that logistic regression, rather than ordinary least squares regression, was more suitable because the former is more appropriate for dependent variables consisting of dichotomous, ordinal data (Varady & Carrozza (2000)). Subject to the number of variables and sensitivity requirements, it is advised that conventional linear regression is preferable, considering the time and resources available for FM benchmarking. It is supported by the fact that numerous satisfactory works related to customer satisfaction have been carried out with linear regression, e.g. the study on casino atmosphere from customers' perspective by Johnson, Mayer and Champaner (2004); the research on quality practices and customer/supplier management in Australian service organizations by Dean & Terziovski (2001); and the examination of hospitals and blood suppliers (Robert and Jami (2004)).

From the FM benchmarking perspective, investigation of the relative importance among individual FM services with regression analysis instead of asking customer to rank the importance may improve the objectiveness of the results. On the other hand, attention should be paid to the risk of omitting a significant FM service in the regression analysis.

As other linear programming methods, data validity may be checked with the Level of Significance. The independent variables (e.g. security comfort level, perception of Guards' attitude, satisfaction on cleanliness of Office Areas) are said to be useful in predicting the dependent variable (e.g. Overall Satisfaction on FM services) when the level of significance is below 0.05.

Consistency analysis is suggested to be carried out along with regression analysis. Correlation and regression analysis are related in the sense that both deal with relationships among variables. The correlation coefficient is a measure of linear association between two variables. Values of the correlation coefficient are always between -1 and +1. A correlation coefficient of +1 indicates that two variables are perfectly related in a positive linear sense, a correlation coefficient of -1 indicates that two variables are perfectly related in a negative linear sense, and a correlation coefficient of 0 indicates that there is no linear relationship between the two variables.

Webster (1995) provides a detailed discussion regarding the problems of multi-collinearity.

3.6 Data Envelopment Analysis (DEA): Analyzing Facility Management Performance

DEA was first introduced by Charnes, Cooper and Rhodes in 1978. It is a linear programming based technique and is usually applied on relative performance measurement of organizational units where multiple inputs and outputs make comparisons difficult. During the last 30 years, DEA has been recognized as a non-parametric method in the fields of operations research and econometrics for multivariate frontier estimation and ranking.

It can combine many performance measures into an indicator of efficiency and help the FM units achieve their goals during the improvement process. The efficiencies assessed are relative in the sense that they reflect the scope for resource conservation and output augmentation at one unit relative to other comparable units.

An FM operation may be considered by the end-users as competent when the qualities of security and cleaning services provided to them exceeded their expectation. However, end-users' satisfaction cannot reflect the complete picture as to whether the FM services are provided efficiently. Facility managers need to know whether the resources are utilized productively. Conventional single measures ignore the interactions and tradeoffs among various performances. In the financial field, return on investment or other ratios are well recognized as a good measure of performance. In some unique services organizations, operations have been standardized: quality and quantity of product outputs per labour and time inputs are clearly described, as seen in large fast food restaurant chains. Where the standardization of FM services has not yet been achieved, benchmarking tools which can measure outputs versus inputs in an empirical sense are required.

The applications of DEA, unlike AHP, are not about structuring a problem and synthesis for a final score. The application of DEA is illustrated below with a simplified 'Inputs-Process-Outputs' system of an FM operation unit:

(1) Inputs: Information, material, energy and labour.

(2) Transformation processes that consumes these inputs to create or sustain something of value.

(3) Outputs in the form of final services.

This can be conceptualized by the following example: A facility manager studies an income statement for the past month. He focuses on the inputs, like machinery depreciation and overhead costs, the efficiency of the processes by which these resources were transformed into product, e.g. gross margin ratio and management fee.

This basic inputs – process – outputs model is generic. The principles are absorbing inputs, and transforming them into outputs of value, as shown in Figure 3.5. Based on Figure 3.5, facility managers may add two ingredients: (1) a benchmark against which to compare the actual performance and (2) another benchmark in the form of a feedback channel to allow information on variance to be communicated and acted upon, as illustrated in Figure 3.6.

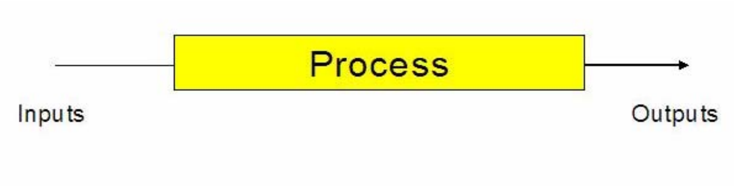

Figure 3.5 Generic Inputs – Process – Outputs model

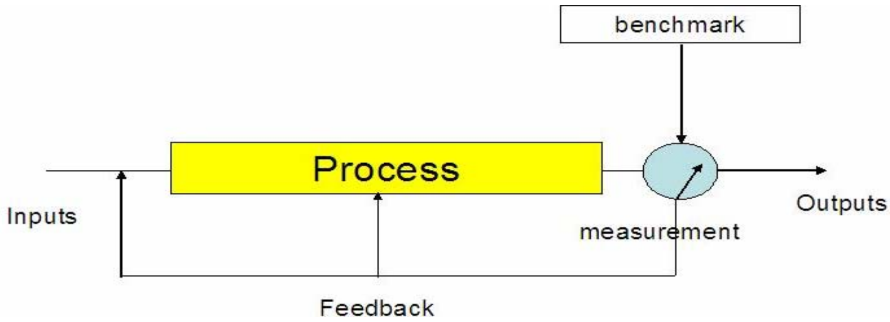

Figure 3.6 Cybernetic Feedback model (Source: Simmons (1999))

An output benchmark is a formal representation of performance expectations. With the preset standards at hand, a facility manager can assess how well inputs have been transformed into outputs. However, a benchmark in itself is not adequate. There must be a way of applying the data: outputs should be compared with standards and use the resulting variance information to change the inputs or process to ensure that performance will be met. Therefore the second ingredient is a feedback channel coupled with an understanding of what adaptations to inputs and process are likely to improve the results. Simmons (1999) pointed out that benchmarking is just like watching the speedometer when driving: *We need to compare the information with highway speed limit sign posts(pre-set benchmark) to decide whether we should accelerate or slow down (process adjustment).* Feedback information can be used in many ways: For example, the facility manager of a call centre can use the feedback information about an operator's superior performance to learn how others can do their jobs better.

During the Xerox era of benchmarking, single-measure gap analyses were common. The benchmarking subjects were confined to costs, profits in monetary terms and energy consumed. Organization performances are now often evaluated in terms of more complicated measures. Apart from completeness of comparison and better consideration of subjects' interactions and tradeoffs, Camp (1995) pointed out another advantage of benchmarking by multiple measurements: Absolute values are not revealed in the benchmarking report.

Multiple measures can incorporate the integration of interactive data but require techniques which are more sensitive. For example, when benchmarking energy and/ or maintenance costs, and the number of users, their inter-relationships are difficult to define. Thus, a better management tool is necessary for accurate FM benchmarking results.

DEA aims to measure how efficiently a Decision-Making Unit (DMU) uses different resources available to generate a set of outputs (Charnes *et al*. (1978)). DMUs can be manufacturing units, departments of big organizations such as universities, schools, bank branches, hospitals, power plants, police stations, tax offices, prisons, a set of firms or even professional individuals such as medical practitioners. DEA has frequently been applied to non-profit organizations, where the measurement of performance efficiency is difficult. It was used to argue that the efficiency of commercial organizations can be easily assessed by their yearly profits, or their stock market indices. However, such measurable factors are not applicable to non-profit organizations.

In DEA calculations, the best performing DMU is assigned as an efficiency score of unity or 100 per cent, and the performance of other DMU vary, between 0 and 100 percent relative to the best performance. As mentioned earlier, the basic efficiency measure used in DEA is the ratio of total outputs to total inputs. In general, inputs can include any resources utilized by a benchmarked organization, and the outputs can range from actual products produced to a range of performance and activity measures. The following hypothetical example with adjusted real data illustrates the basics of DEA. The data was extracted from an internal benchmarking survey by a property investment company in Hong Kong in the year of 2003.

Mr. Chan is a facility manager of a property investment company in Hong Kong. The property investment company owns two office buildings, Building A and Building B, in the same district with comparable services and lessee compositions. Mr. Chan is given a duty “to present to the company executives on how efficient the two FM units of the two buildings among their peers are”. Mr. Chan only managed to collect the following data for benchmarking Buildings A and B with other fourteen other comparable buildings in the same district:

1. Building services (BS) cost per square feet: BS cost includes the costs relating to the services of electricity, air conditioning, plumbing and drainage, sea water system (if applicable), fire, vertical transport as well as general cleaning.

2. Rent per square feet.

Despite the lack of other conventional FM data for benchmarking, Mr. Chan is convinced that meaningful information can still be drawn from the benchmarking study with the use of DEA because:

1. The BS cost represents a substantial operation cost of the whole building’s

facilities.

2. Though rent is largely determined by demand and supply within its market segment, it reflects the competitiveness of the quality of FM services, assuming that the property market is perfect with respect to information and market competition.

3. When assessing organizations' efficiency with DEA, financial evaluations were not necessary. DEA only requires activity information (Homburg (2001)).

From Table 3.5, some statements concerning the relative efficiency of the buildings can be made:

1. BS cost of Building A is lower while rental per square feet charged is higher than Building B. Clearly if the input and output are representative, Building A's FM unit is more efficient than Building B's.

2. Building A and Building 4 have the lowest cost in building services. The two buildings may be considered as the most productive from this limited aspect. However, from the same table, it was noted that the rent per square feet of Building 3 is the highest among the 16 buildings.

Table 3.5 Building services cost and rent per square feet of 16 buildings of the year 2001

Building	BS cost per square feet (HKD) per year	Rent per square feet
A	59	19
B	74	18
1	65	17
2	76	17
3	75	20
4	55	16
5	63	18
6	58	19
7	76	17

8	72	19
9	65	18
10	75	19
11	59	16
12	67	18
13	69	18
14	63	19

(Source: An internal benchmarking survey by a property investment company in Hong Kong in 2003)

The annual cost for building services per square feet and the rent per square feet are plotted for each building in Figure 3.7: Buildings A, 3, 4, 6 and 14 form an "efficiency frontier". It was named so because they produce the most outputs in closed cases for a reported amount of costs. Buildings close to the frontier are relatively efficient and those inside the frontier are less efficient. The facility manager of Building B may either become as efficient as A by decreasing its cost on building services or by increasing the rent charged, become similar to Building 3. These possible transformations of Building B's FM unit to those efficient ones near the frontier demonstrate the basic idea of DEA.

As shown, a facility manager can develop an empirical efficient frontier based on his own observation as a benchmark with limited data. However, DEA users are always suggested to collect more data of representative performance measures and incorporate these to refine the model and check any breakthroughs on the frontier with up-dated data. In the paper by Schaffnit *et al.* (1997), it was shown that DEA can deal with 291 benchmarking participants with 5 inputs and 8 outputs.

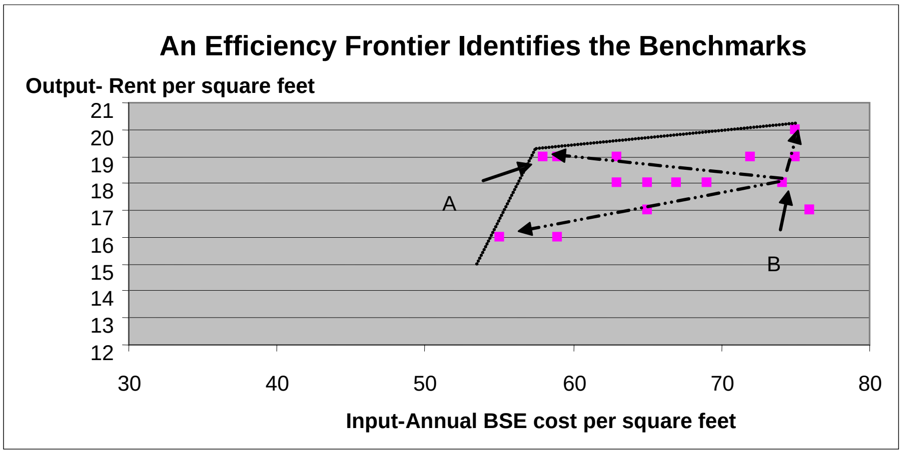

Figure 3.7 An Efficient Frontier identifies the Benchmarks

In this case, DEA can indicate the exact targets for the inefficient units with reference to the efficient ones diagrammatically. Facility Managers can thus check the improvement progress against time from the diagram. Benchmarks may be given in terms of inputs or outputs:

Table 3.6 Efficiency report for Building B

	Observed measure (HKD)	Benchmark (HKD)	Potential improvement (HKD)
Output: rent per square feet	18	20	2 (increase)
Input: BS cost per square feet per year	74	55	19 (reduction)

From FM perspectives, advantages of applying DEA for benchmarking are:

1. It is consistent with the services production theory;
2. No functional form assumption is required;
3. Multiple inputs and outputs are analyzed without defining weights;
4. Qualitative outputs may be included;
5. Efficiency improvement is encouraged.

On the other hand, its disadvantages are:

1. It only measures relative efficiency;
2. Specification of inputs and outputs is necessary;

3. It is difficult to obtain complete ranking.

It is submitted that DEA is suitable for interpreting and analyzing FM quantitative information.

In the two case studies, cost oriented DEA models or input oriented models are applied. The objective of a facility manager is to achieve a specific output bundle from the minimum quantity of input.

3.7 Comparison of Facility Managers' Comprehension and Customer Satisfaction Survey Results

Understanding of customers' needs gives facility managers a focus for providing services that meet customers' demands and enabling resources prioritization. The closer match between the FM services quality and the customer expectation imply a better chance of FM contract renewal. The understanding of their customers' needs is thus an integral concept for the focus of facility managers' strategic decisions and continuous improvement efforts. (Bounds & Yorks *et al (1994)*).

The necessity of identifying the gap between facility managers' comprehension and customers' needs calls for a sub-system in the proposed framework (Figure 3.3, page 46) to compare the two. A statement by L. D. DeSimone, Chairman, Minnesota Mining and Manufacturing Co. (3M) reflects the rational for comparing the two:

> *The concept of quality transcends product* ***performance*** *and encompasses all aspects of* ***customer satisfaction****. Customers not only want a product that* ***performs*** *exactly to their* ***requirements****, they want their orders to* ***be handled as efficiently as possible****. Continuous improvement of quality and customer satisfaction is essential in today's marketplace. In many cases it is not just a success factor, it is a survival factor.*

The subsystem for comparison of facility managers' comprehension and customers' value within the proposed framework will help facility manager make better judgment with a focus on their customers' needs. In the investigation of Campbell and Finch (2004) on maintaining customer satisfaction, the importance of a two-way communication between customers and facility managers is emphasized. Facility managers should know customers' demands and customers should be informed of the FM constraints. In the proposed benchmarking framework, both customers' demands and facility managers' judgements are investigated to minimize the gap between the demand and supply for FM services. FM staff and customers are only satisfied at an equilibrium point where the demand and supply of FM services are balanced.

3.8 Matching of Hard and Soft Data

Both hard and soft data are very important to the success of an FM benchmarking study. Hard data is required for the measurement of FM operation efficiency and soft data is a function in the calculation of FM process effectiveness. The FM measurement window of Kincaid (1994), as illustrated in Figure 3.8, shows how hard and soft data of FM are organized systematically under the category of support service and the working environment. Kincaid successfully illustrated the organization of FM information in the process of benchmarking. With reference to Kincaid, FM measurement table should be drawn both in the planning and analysis stages of each benchmarking study. The measurement table serves as a map showing which hard data should be taken with respect to customers' needs.

Kincaid's "FM measurement window", although useful in terms of structuring normal FM services benchmarking data is not definitive. Other 'hard data' related to mechanical and electrical engineering services are also applicable as well as utilities and telecommunication systems. These may be interpreted as facility-oriented benchmarking indicators. On the other hand, a business may see these issues as less important, preferring to measure performance in terms of customer growth/ retention, organizational and operations.

With FM soft data (e.g. customer satisfaction and their perception on the relative importance of different FM services), facility managers can make better use of available resources. For example, based on a customer survey, facility managers may find that their customers perceive security as being the most important and need substantial improvement; at the same time it may be noted that the importance of cleaning services in common area is over-estimated and its ‘supply of service’ is much higher than demand. The facility manager may consider diverting resources from cleaning to security. Matching of data is also a prerequisite for DEA calculation: *For a given output vector, a consumption set consisting of all input vectors that may produce the output set is required*. (Charnes, Cooper and Rhodes (1978))

	Hard data	Soft data
Support service	1. Service and operation costs 2. Failure rates	1. Cleanliness 2. Perception on security level 3. Responsiveness
Working Environment	1. Temperatures 2. Lighting levels	1. Comfort 2. Interior image

Figure 3.8 FM Measurement Window (Kincaid (1994))

Chapter 4 Case Study 1 – Local Internal Benchmarking

In this case study, the FM department of a property investment company, ABC (the Company), was examined. The fourteen buildings in this study are located in different districts of Hong Kong. Four are office buildings for internal use. The rest are used for both operation and storage of machines and as offices for internal staff.

FM data of the fourteen building of the year 2004 was collected as part of cost analysis and customers' satisfaction survey. The objective of this case study is to examine the effectiveness and efficiency of the Company's FM unit on the management of the 14 buildings. The FM benchmarking framework proposed in Chapter 3 was tested in this case study.

4.1 Description of the Organization and its Facility Management unit

The FM unit of the Company outsourced all cleaning and security services of the fourteen buildings. The relationships between the Company and the services providers are mainly 'compliance and controls' based. It is centred upon the obligations set out in contract documents. KPIs, service levels and contract sum were determined mainly reference to building floor area. FM contracts were made at the beginning of each financial year and variations during the contract period are difficult. Good FM planning is crucial to the control of FM cost. However, the FM budget planning did not take the customers' satisfaction into account. This is not unusual in Hong Kong, where cost efficiency is often viewed as paramount and has precedence over customer related issues. The Company, a telecommunications firm, at the time of the case study was primarily driven by the need to reduce cost where practical.

Buildings for technical use, where electrical and electronic machines are stored and operate, serve 24 hours a day. The following FM duties with respect to the outsourced services are monitored by the Company's FM unit:

1. Quality of work
2. Responsiveness and timely delivery of services
3. Cost control
4. Safety performance
5. Environmental compliance
6. Scheduling and planning of current and future work
7. Customers' satisfaction levels

The FM unit carried out a customers' satisfaction survey in December 2004. The survey covered overall satisfaction level by perception and satisfaction levels of six other specific items:

1. Security comfort level
2. Attitude of guard
3. Cleanliness of common areas
4. Cleanliness of office areas
5. Cleanliness of pantry
6. Cleanliness of washroom

It was noted that the overall satisfaction by perception may cover other sectors and the overall satisfaction on FM was not defined in the survey. Relative importance among the six items was not included in the survey. With reference to the proposed FM benchmarking framework (Figure 3.3), the following tasks were performed in this study:

1. Data sets matching
2. Regression analysis of the soft aspects of FM Performance
3. AHP analysis of the soft aspects of FM Performance; Comparison of facility managers' Judgment and Customers' satisfaction Survey Data
4. FM Performance evaluation with DEA

4.2 Profile of Participating Buildings

Building types and response rate of the customers' satisfaction survey are given below:

Table 4.1 Buildings in the analysis

Building No.	Building type	Response rate of customers' satisfaction survey (%)
1	OFFICE	15
2	OFFICE	13
3	OFFICE	38
4	TECHNICAL	34
5	TECHNICAL	19
6	TECHNICAL	24
7	TECHNICAL	7
8	TECHNICAL	15
9	TECHNICAL	21
10	TECHNICAL	14
11	TECHNICAL	42
12	OFFICE	19
13	TECHNICAL	33
14	TECHNICAL	13

The overall response rate of the survey was 17%, with over 1,000 participants. A summary of survey data may be found in Appendix A. The average values of overall satisfaction level and the 6 chosen items of each building (in the scale of 1-5, where 1 stands for 'very poor' and 5 stands for 'very good') are listed below:

Table 4.2 Summary of survey results

Building No.	Overall Satisfaction	Security comfort level	Attitude of guard	Cleanliness: Common Areas	Cleanliness: Office Areas	Cleanliness: Pantry	Cleanliness: Washroom
1	3.50	3.67	4.06	3.86	3.47	3.55	**2.81**
2	3.70	3.72	3.90	3.81	3.39	3.21	3.45
3	4.16	3.94	3.90	3.58	3.81	3.69	3.53
4	3.84	4.06	4.14	4.14	4.00	3.81	3.61
5	3.59	4.08	4.49	3.77	3.21	3.05	**2.44**
6	3.82	3.68	4.00	3.68	3.60	3.61	3.66
7	3.79	3.63	3.90	3.78	3.21	3.22	**2.93**

8	3.67	3.63	4.07	3.75	3.49	3.27	**2.97**
9	4.28	3.99	4.14	4.39	4.00	3.74	3.63
10	4.02	3.92	4.35	3.94	3.60	3.50	3.43
11	3.60	3.41	3.69	3.79	3.53	3.58	3.40
12	3.69	3.38	4.09	3.99	3.60	3.55	3.14
13	3.79	3.63	3.88	3.89	3.73	3.67	3.46
14	3.58	3.90	4.28	3.78	3.29	3.07	3.18

4.3 Objectives and Method

The objective of this case study is to examine the effectiveness and efficiency of the Company's FM unit in the management of the 14 buildings. Throughout the examination, the applicability of the proposed FM benchmarking framework was tested.

As mentioned in the previous chapter, efficiency of the FM unit on the building management was measured by the ratio of its inputs to its outputs. The objective of efficiency improvement was to minimize inputs while outputs were assumed to remain constant.

Effectiveness is a complicated concept and definitions of it vary considerably. A widely accepted definition is that effectiveness is the degree of success of activities or services in meeting their objectives. Effectiveness of the FM unit on the management of the buildings will be investigated with main reference to customers' satisfaction.

Referring to section 3.8 and section 4.1, the collected data was first organized in hard and soft sets. For the DEA analysis, the collected data was arranged in vectors of inputs and outputs.

Task 1 Matching of data sets

Both hard and soft data are very important to the success of FM benchmarking study. Hard data is required in the measurement of FM operation efficiency and soft data is a function in the calculation of FM process effectiveness. Matching of the data sets means: (i) All categories of data collected should be relevant to FM practice and benchmarking objective; (ii) In the DEA calculation, a prerequisite is, for a given output vector, a consumption set consisting of all input vectors that may produce the output set is required (Charnes, Cooper and Rhodes (1978)).

As shown in Table 4.3, the FM inputs are matched with the FM outputs in the benchmarking study:

Table 4.3 Inputs and outputs of the FM operation

FM Inputs	FM Outputs
Cleaning cost	Customers' satisfaction on Common Areas Cleanliness
	Customers' satisfaction on Office Cleanliness
	Customers' satisfaction on Pantry Cleanliness
	Customers' satisfaction on Washroom Cleanliness
Security cost; Maintenance Fee (security system)	Customers' satisfaction on Guard Attitude
	Customers' satisfaction on Security
Energy Use	Number of staff
	Office area
	General Customers' satisfaction on FM services
	Equipment area

4.4 Data Analysis

Task 2: Regression analysis of soft aspects of FM Performance

By linear categorical regression with the SPSS program, three sets of tests were done with the data in the customers' satisfaction survey to investigate the relative importance of the six FM items within customers' perception on the overall FM services. The overall satisfaction scores are set to be the only dependent and the other six FM items are set to be independent of the following linear relationship:

Overall satisfaction = security comfort level (W_1) + attitude of guard (W_2) + cleanliness of common areas (W_3) + cleanliness of office areas (W_4) + cleanliness of pantry (W_5) + cleanliness of washroom (W_6)

where W_1, W_2 … W_6 are respective relative weights of customers' satisfaction on:

1. Security comfort level
2. Attitude of guard
3. Cleanliness of common areas
4. Cleanliness of office areas
5. Cleanliness of pantry
6. Cleanliness of washroom

Nine buildings for technical use were examined. The respective weights of the six categories were found and given below:

1. Security comfort level (0.28)
2. Attitude of guard (0.11)
3. Cleanliness common areas (0.17)
4. Cleanliness office areas (0.11)
5. Cleanliness pantry (0.15)
6. Cleanliness washroom (0.19)

The level of significance is below 0.05. Therefore the independent variables (i.e. the figures of satisfaction level) are said to be useful in predicting the dependent variable (i.e. the relative weight).

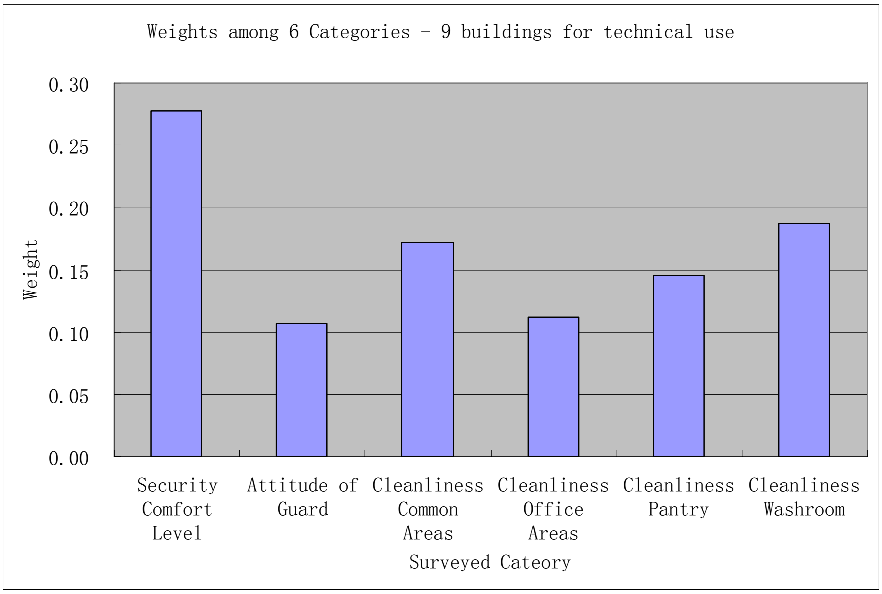

Figure 4.1 Technical buildings: Relative weight of six FM services

Four office buildings are examined. The relative weights of the six categories using linear regression based on the data from the customers' satisfaction survey were:

1. Security comfort level (0.27)
2. Attitude of guard (0.08)
3. Cleanliness Common Areas (0.27)
4. Cleanliness Office Areas (0.16)
5. Cleanliness Pantry (0.01)
6. Cleanliness Washroom (0.20)

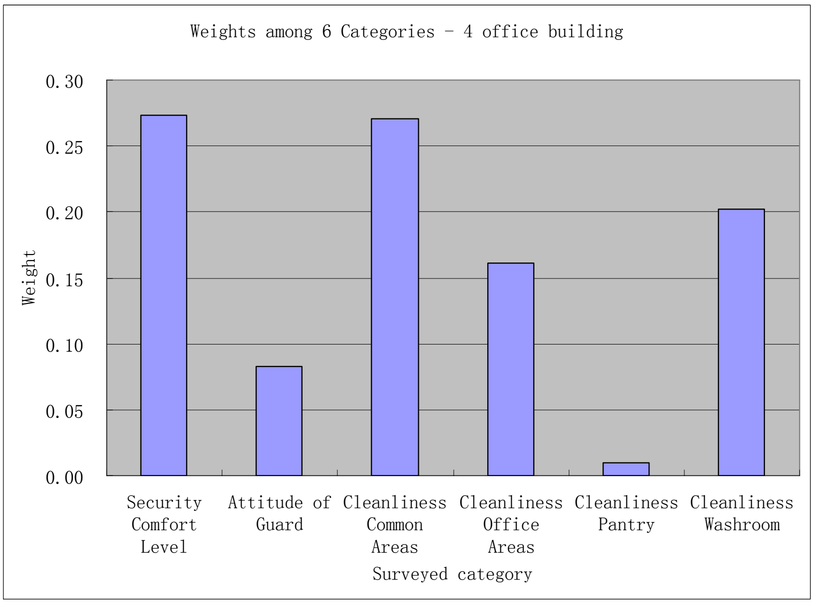

Figure 4.2 Office buildings: Relative weight of 6 FM services in satisfaction survey (1-5 scale was used in customers' satisfaction survey)

The level of significance is below 0.05, except for the category of cleanliness of pantry due to data insufficiency – not all offices have pantry. Therefore the independent variables (i.e. the figures of satisfaction level) are said to be useful in predicting the dependent variable (i.e. the relative weight).

According to the regression analysis on the customers' satisfaction survey, the following observations were made:

1. Security comfort level is the most important according to customer perception. It is true for both building types.
2. Compared with those in buildings for technical use, customers in office buildings perceive cleanliness in common areas as more important.
3. The relative weight of cleanliness in office area in buildings for technical use is found to be low. It may be because there is less office area in those buildings.
4. The importance of levels of cleanliness in washrooms is similar in both building types.
5. The importance of levels of attitude of guard is similar in both building types.
6. Regarding the cleanliness of the pantry, it was observed that the frequency of use and the building type (office/ technical) had observable significance.

However, the issues, such as size, the available resources, such as appliances, provision of coffee/ tea my also influence levels of satisfaction.

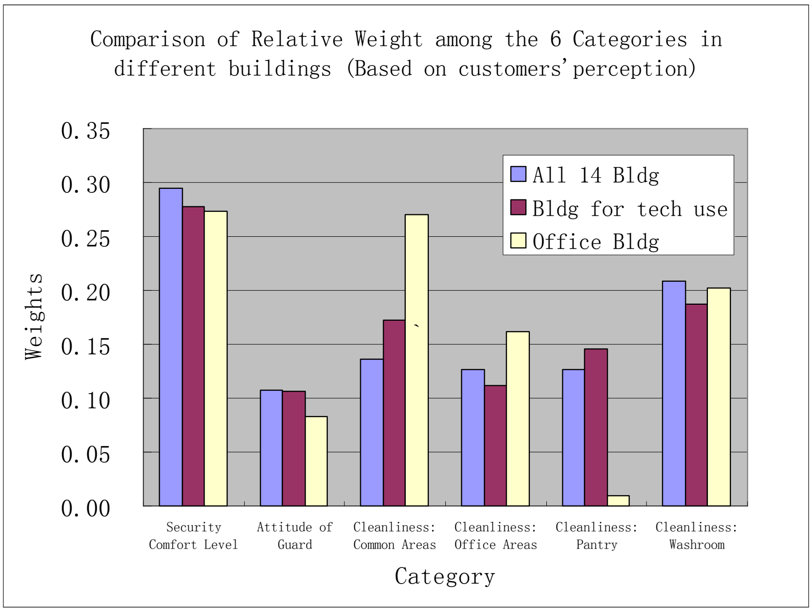

Figure 4.3 All buildings: Relative weight of six FM services

The above-mentioned observations are expected to help the facility managers in the development of KPI or services level agreements when new FM contracts are negotiated with service providers. The following implications may be drawn:

1. To maximize the effectiveness of FM operation, facility managers should put more resources on the FM services which are considered to be more important. Based on the above findings on the satisfaction level and relative importance, the facility manager may consider enhancing the services level of common area cleanliness while reasonably reducing the services level of office areas for buildings of technical use. It is expected that the overall customer overall satisfaction will be improved without significant impact on FM budget.
2. With reference to the high relative importance and existing customers' satisfaction of the security comfort level and attitude of guard, any proposal of resources reduction about security is not wise. Change of service providers or service level adjustments may be risky.

3. Educating customers about washroom cleanliness may help to lessen the FM budget spent on washroom cleanliness and improve the customers' satisfaction.

Separate investigations on male and female washrooms cleanliness at different building types should be conducted. Different services levels may be set for washrooms in different types of buildings with reference to the proportion of male and female employers.

Task 3: AHP analysis of soft aspects of FM Performance; Comparison of Facility Managers' Judgment and Customers' satisfaction Survey Data

The facility managers' understanding of their customers' needs and the relative importance of six FM items to the overall FM services quality from the perspectives of the facility manager in-charge were examined. The examination results were compared with the regression results.

AHP was applied to investigate the judgment of the facility manager in-charge of the six FM items' relative importance for both building types. The same facility manager was also asked to rank the importance in the scale of 1-5, where 5 represents very important and 1 represents not important at all. The judgments of the facility manager in charge are summarized in Tables 4.4 and 4.5.

The FM benchmarking framework includes an AHP application to dynamically rank the importance of FM items based on the facility manager's relevant past experience (i.e. accuracy in estimation). If a group of facility managers is available, a Delphi approach may be used.

Table 4.4 Buildings for technical use: Relative importance of six FM items

	Security comfort level	Attitude of guard	Cleanliness: common areas	Cleanliness: office areas	Cleanliness: pantry	Cleanliness: washroom
Normalized relative weight	0.208	0.125	0.167	0.167	0.167	0.167
Relative weight (By AHP method)	0.500	0.100	0.100	0.100	0.100	0.100

Table 4.5 Office buildings: Relative importance of six FM items

	Security comfort level	Attitude of guard	Cleanliness: Common Areas	Cleanliness: Office Areas	Cleanliness: Pantry	Cleanliness: Washroom
Normalized Relative weight	0.154	0.115	0.154	0.192	0.192	0.192
Relative weight (By AHP method)	0.085	0.037	0.097	0.17	0.248	0.362

Different ratings with similar ranks were observed when different methods were used. AHP results appeared with larger deviations. Generally both results were consistent with each other.

Compared with the regression results, significant difference was noted in the ranking related to office buildings. For example, the user's perceived security was the most important; whereas facility managers indicated that the washroom's cleanliness came first. The difference may imply communication fault lines between the facility manager and the customers. It is also likely that facility manager may underestimate the importance of security.

Task 4: FM Performance evaluation with DEA

In the DEA calculations, the inputs of the FM operation are cleaning cost, security cost, maintenance fee (security system) and Energy Use. Outputs are the number of staff; office area, equipment area and customers' satisfaction of the following six FM categories: common areas cleanliness, office cleanliness, pantry cleanliness, washroom cleanliness, guard attitude and security. Only nine buildings are assessed with DEA due to data availability.

In DEA calculation, the best performing unit is assigned an efficiency score of unity or 100 per cent, and the scores of inefficient units vary between 0 and 99.9 percent relative to the best performance. The analysis results are illustrated in Table 4.6.

Table 4.6 DEA calculation results with 4 inputs and 9 outputs

Building	Input-Oriented Efficiency
Building 4	0.79019
Building 6	1.00000
Building 7	1.00000
Building 8	1.00000
Building 9	1.00000
Building 10	1.00000
Building 11	1.00000
Building 13	0.77723
Building 14	0.82649

In this analysis, an input-oriented scenario was assumed. That means outputs were fixed at constant level and inputs were minimized to produce the given level of outputs. Buildings 4, 13 and 14 were assessed to be inefficient relative to the rest. Table 4.7 shows the input targets found for the three buildings:

Table 4.7 Efficient Input targets

Building name	Total cleaning cost	Total Maintenance Fee (security system)	Energy Use (kWh)	Total security cost
Buildings 4	-28%	-21%	-21%	-56%
Buildings 13	-22%	-80%	-22%	-68%
Buildings 14	-22%	-39%	-17%	-56%

Instead of applying the customers' satisfaction of six individual FM categories as outputs of DEA calculations, the same analysis was carried out with the general customers' satisfaction of the overall FM service as an output replacing the six categories. Similar results were found, as illustrated in Tables 4.8 and 4.9.

Table 4.8 DEA calculation results with 4 inputs and 4 outputs

Building No.	Input-Oriented Efficiency
4	0.73980
6	1.00000
7	1.00000
8	1.00000
9	1.00000
10	1.00000
11	1.00000
13	0.75371
14	0.84200

Table 4.9 Efficient Input targets

Building No.	Total cleaning cost	Total Maintenance Fee (security system)	Energy Use (kWh)	Total security cost
4	-33%	-26%	-26%	-57%
13	-25%	-80%	-25%	-69%
14	-29%	-52%	-16%	-50%

A common problem in the application of the Likert scale was noted. In the satisfaction survey, customers were asked to rate the services quality in five ratings:

1. Very good (5)
2. Good (4)

3. Fair (3)
4. Poor (2)
5. Very poor (1).

In the above linear regression analysis and DEA calculation, the five ratings were presented by a numerical scale of 1-5 as illustrated. According to the numerical scale, the sum of 'very poor' grades given by 5 customers is equal to a 'very good' grade given by a customer. To rectify this irrationality, a scale of -2 to +2 is applied to replace the scale of 1-5. The results of regression analysis and DEA calculation with the scale of -2 to +2 were shown in Tables 4.24 - 4.30. A significant difference was observed in the DEA calculation, as Building 4 was assessed to be relatively efficient when the scale of -2 to +2 was used. It is submitted that the difference is due to the fact that the data envelope has been reformed when the new scale of -2 to +2 was used. It was also noted that DEA cannot accept negative inputs and outputs.

In this application of DEA, negative input or output does not mean that input or output is negative. It simply means that they are undesirable. For instances, they could be undesirable outputs like pollution. It is therefore submitted that this problem may simply solved by shifting the scale. Alternatively, with reference to Sharp, Meng & Liu (2005), a Modified Slacks Based Measure model may be applied to accommodate the negative inputs and outputs. The discussion is out of scope of the present research.

A correlation analysis is given in Table 4.17. From the analysis, it is noted that the FM items related to cleanliness are more correlated. The correlation co-efficient of the FM items related to cleanliness range from 0.45 to 0.607 while the same of the FM items not related to cleanliness range from 0.144 to 0.435. This may be explained by the fact that the cleaning services of all places are outsourced to the same contractor. The impressions of customers on different places' cleanliness may have influences on one another. According to the Company representative, the six FM services items are assumed to be completely independent.

In theory, the independent variables in a regression need to be uncorrelated with each other. When there is multi-collinearity - correlation across independent variables:

1. The coefficients on each of the independent variables become much more difficult to read in isolation, since variables start to approximate for each other.
2. The reported t-statistics tend to overstate the significance of the relationship.
3. The regression still has predictive power

Perhaps the most direct way of testing and detecting multi-collinearity is to produce a correlation matrix analysis for all variables, as shown in Table 4.17. (Webster (1995))

Table 4.10 Technical buildings: Relative weights of six FM services in satisfaction survey via regression analysis

FM services in satisfaction survey	Normalized relative ratings
Security comfort level	0.271

Attitude of guard	0.201
Common Areas Cleanliness	0.246
Office Areas Cleanliness	0.017
Pantry Cleanliness	0.152
Washroom Cleanliness	0.113

Notes: -2 - +2 scale was used in customers' satisfaction survey

Table 4.11 Office buildings: Relative weight of six FM services in satisfaction survey via regression analysis

FM services in satisfaction survey	Normalized relative ratings
Security comfort level	0.230
Attitude of guard	0.206
Common Areas Cleanliness	0.161
Office Areas Cleanliness	0.127
Pantry Cleanliness	0.174
Washroom Cleanliness	0.102

Notes: -2 - +2 scale was used in customers' satisfaction survey

Table 4.12 All buildings: Relative weight of six FM services in satisfaction survey via regression analysis

FM services in satisfaction survey	Normalized relative ratings
Security comfort level	0.263
Attitude of guard	0.202
Common Areas Cleanliness	0.213
Office Areas Cleanliness	0.09
Pantry Cleanliness	0.117
Washroom Cleanliness	0.115

Notes: -2 - +2 scale was used in customers' satisfaction survey

Table 4.13 DEA calculation results with 4 inputs and 9 outputs

Building	Input-Oriented Efficiency
Building 4	1.00000
Building 6	1.00000
Building 7	1.00000
Building 8	1.00000
Building 9	1.00000
Building 10	1.00000
Building 11	1.00000
Building 13	0.88918
Building 14	0.88494

Notes: -2 - +2 scale was used in customers' satisfaction survey

Table 4.14 Efficient Input targets with 4 inputs and 9 outputs

Building name	Total cleaning cost	Total Maintenance Fee (security system)	Energy Use (kWh)	Total security cost
Buildings 13	-11.1%	-71.5%	-20.8%	-52.4%
Buildings 14	-11.5%	-15.4%	-11.5%	-38.0%

Notes: -2 - +2 scale were used in customers' satisfaction survey.

Table 4.15 DEA calculation results with 4 inputs and 5 outputs

Building No.	Input-Oriented Efficiency
4	0.79672
6	1.00000
7	1.00000
8	1.00000
9	1.00000
10	1.00000
11	1.00000
13	0.72650
14	0.82649

Notes: -2 - +2 scale was used in customers' satisfaction survey

Table 4.16 Efficient Input targets with 4 inputs and 5 outputs

Building name	Total cleaning cost	Total Maintenance Fee (security system)	Energy Use (kWh)	Total security cost
Buildings 4	-27.8%	-20.3%	-20.3%	-55.4%
Buildings 13	-27.3%	-69.1%	-43.5%	-59.3%
Buildings 14	-21.7%	-39.5%	-17.4%	-56.5%

Notes: -2 - +2 scale were used in customers' satisfaction survey.

Table 4.17 Correlation Analysis

	Security Comfort Level	Attitude of Guard	Cleanliness Common Areas	Cleanliness Office Areas	Cleanliness Pantry	Cleanliness Washroom

Security Comfort Level	1.000					
Attitude of Guard	0.435	1.000				
Cleanliness Common Areas	0.310	0.281	1.000			
Cleanliness Office Areas	0.298	0.221	0.607	1.000		
Cleanliness Pantry	0.248	0.144	0.527	0.606	1.000	
Cleanliness Washroom	0.319	0.216	0.450	0.521	0.604	1.000

4.5 Improvement Implementation

Results of DEA calculations, regression analysis and AHP can be integrated for improvement action. For example, it was noted that customers' satisfaction of Buildings 1, 5, 7 and 8 on washroom cleanliness was below the rating of 2. With the AHP method, the facility manager-in-charge recognized the importance of washroom cleanliness, especially for office buildings. The FM unit may consider setting a new output benchmark and through DEA calculations to estimate the possible minimum inputs involved. Such applications would be elaborated in case study two of next chapter.

Change of cost, e.g. increase of electricity and oil prices, may influence improvement implementation and FM policy. In the proposed FM benchmarking framework, relative weight of inputs may be adjusted to reflect the real situation. For instance, the relative weights of total cleaning cost, total maintenance fee of security system, energy use kWh and total security cost were adjusted in the proportion of 1: 1: 2: 1 in the DEA calculations to simulate the effect on electricity cost increase, it was found that the influences on Building No.13 and No. 14 are more serious, compared to other buildings for technical use. The efficiency score of Building No.13 is reduced from 89% to 62%. The score of Building No.13 is reduced from 89% to 79%. Detailed calculations are given in Appendix A.

4.6 Results

Efficiency and effectiveness of the FM unit on the management of the 9 technical building were investigated. Buildings 4, 13, 14 were found to be relatively inefficient. Based on theories of linear regression, AHP and DEA, efficiency and effectiveness of the FM units may be improved by better allocating resources on the items which are considered to be more important by customers.

In a meeting with the Company, a facility manager enquired about the relative weights among the multiple inputs and outputs in the DEA calculations. Based on the theories of DEA, multiple inputs and outputs were usually analyzed without defining relative weights. It is submitted that all units being compared are with similar services production process and, therefore, they should have the same relative weights for their inputs and outputs.

4.7 Conclusions and Development of the Framework

In this case study, the proposed FM benchmarking framework was tested. Further application of the framework was proposed to the Company in the process of improvement execution, for example, setting an acceptable level of customers' satisfaction as benchmarks in DEA calculations to find the necessary additional inputs. Further trial and development of the framework are possible when data and information about improvement actions and their results are collected.

4.8 Test of Hypothesis

Referring to Section 1.8, the following lessons were learnt in this case study.

Referring to hypothesis 1, in this case study the main influence of outsourcing, specifications development and FM planning on application of benchmarking is related to the FM planning and outsourcing schedule. The Company confirms outsourcing agreements with providers at the beginning of the financial year. Reference is seldom made to the most updated benchmarking study or customers' satisfaction survey since these studies are often not completed when the outsourcing contracts are initiated. A viable solution is to shorten the time required for benchmarking study or customers' satisfaction survey. Survey on Internet and a systematic FM benchmarking framework can shorten survey time (Wober (2002)).

Referring to hypothesis 2, the amounts and dimensions of information & implications deduced from benchmarking study are positively associated with the accomplishments of benchmarking projects only if they are presented and processed with a systematic approach. The difficult issue is that much information collected is inter-related and, sometimes, contradictory.

The FM process was simplified for better understanding by sorting the information into categories of inputs and outputs.

Referring to hypothesis 3, in the Company, facility managers' intuitive or personal experiences are important to the planning and executive of FM benchmarking. It was observed that properties and facilities of the Company are managed by a group of professional facility managers in a definite structure. The effectiveness of FM benchmarking can be improved with a well-developed decision making structure and decision making tools, e.g. AHP or Delphi methods. Periodic benchmarking and performance measurement play an important role of telling any major differences between customers' demands and managerial judgments, especially when wrong steps were executed.

Referring to hypotheses 4 and 6, it was theoretically proved in the case that DEA and AHP can offer more guidelines for FM improvement policies formulation. Risks of improvements executions can be reduced if FM operations are measured periodically. Nevertheless, as pointed out by the facility managers of the Company, the proposed improvement targets may be difficult to be achieved. Some unique site or building factors are not taken into account by the FM benchmarking framework, e.g. lack of car parks.

Referring to hypothesis 5, DEA together with AHP offer multi-dimensional analysis in the process of FM benchmarking. Flowcharts, balanced scorecards, bar charts and polar graphs do not present the full picture of AHP and DEA findings.

Customer satisfaction metrics help a facility management team to evaluate and rank levels of importance. They also enable the team to identify trends over several periods. Rankings and trends help the FM team to focus an area that needs improvement. In addition, 'gap analysis' usefully identifies results consequent to actions. Nevertheless, carrying out a survey may be considered to be only the aspect of providing excellence in FM service. Implementing suggested improvements and responding to individual comments received are also essential.

Chapter 5 Case Study 2 – External Benchmarking

This chapter examines a case of external benchmarking with the aim to better understand the interaction between hard and soft FM data. Comparison will be made between benchmarking only based on hard data and benchmarking with both hard and soft data. The intention of this study is to analyze the significance of incorporating soft data into FM benchmarking. The strengths and limitations of applying DEA in FM benchmarking will also be investigated.

5.1 Source of Data

The data were collected from a major university consortium of facility management. The data covered institutions in the tertiary education sector of Australia, New Zealand, Hong Kong and Singapore. Since 2001, a benchmarking group under the consortium has collected cost and performance data under the following headings:

- Basic statistical data of the campus
- Building maintenance
- Refurbishment
- Backlog liabilities
- Cleaning & waste management
- Security
- Ground maintenance
- Recycling
- Water consumption

- Energy usage
- Parking
- Operation costs

5.2 Description of Data Sets

In this case study, FM data of institutions in Australia and Asia were collected from 1993 to 2003. Number of participating institutions during the 10 years is listed in Table 5.1.

Table 5.1 Number of participants in the benchmarking group

Year	Number of participants in the benchmarking group	Number of institutions analyzed in this case	Number of institutions with both hard and soft data analyzed in this case
1993	24	22	N/A
1994	35	14	N/A
1995	39	21	N/A
1996	55	17	N/A
1997	63	20	N/A
1998	62	26	N/A
1999	63	28	N/A
2000	66	33	10
2001	69	32	10
2002	72	31	7
2003	72	29	10

Due to lack of data, some participating institutions cannot be included in this case study. Lesser institutions were considered when both hard and soft data were analyzed with DEA. Based on the theory of DEA, more efficient institutions than inefficient ones were identified because of the small sample size.

In the research of DEA application in other industries, lack of data and small sample size are commonly considered as weakening the strengths of DEA. As commented by Cullinane *et al.* (2004), the most likely solution is to collect more observations to enlarge the sample analyzed. The data insufficiency in participating institutions also compelled reduction of input and output categories. For example, the total maintenance cost was used as a single category of input.

Some participating institutions cannot fulfill their commitment for a minimum period of three annual comparisons to allow refinement of the measurement set. An investigation based on yearly trend could not be established without caveats. In addition, to avoid the influence of temporary and cyclical factors, such as the Asian financial crisis in the late 1990s, we only examined Australian institutions in this study.

5.3 The Database

In March 2005, Mr. Robert Kelly of Macquarie University was invited by The Hong Kong Institute of Facility Management to give a talk on the benchmarking project on behalf of the benchmarking group. With the collected data Kelly demonstrated a database developed by Currie & Brown and the benchmarking group (TEFMA (2004)).

In the database, participating institutions were categorized according to their locations. Three categories are identified: Central Business District (CBD), suburban and rural. Within each category, mean, median, minimum and maximum are given for each of the following items:

1. Gross Floor Area (Total Campus)
2. Useable Floor Area (Total Campus)
3. Asset Replacement Value (ARV) of Buildings
4. ARV of Infrastructure
5. EFTSU
6. Number of Staff
7. Staff Salaries & On-costs of campus maintenance unit
8. Maintenance Expenditure
9. Area Maintained from Central Funds
10. Customer Satisfaction Rating on maintenance
11. Backlog Liabilities
12. Wages of cleaning staff
13. Cleaning Materials cost
14. Customer Satisfaction Rating on cleaning
15. Annual Energy Consumption
16. Total GFA services with energy
17. Salaries/wages & On-costs related to Ground Maintenance
18. Materials & Contracts cost on Ground Maintenance
19. Customer Satisfaction Rating on Ground Maintenance
20. Security Staff Salaries/wages & On-costs
21. Expenditure on Security Contracts
22. GFA under Security Patrol
23. Customer Satisfaction Rating on Parking
24. Total Water Consumption
25. Total Cost of Purchasing Water

According to Professor McKinnon's proposal for the benchmarking project, it was expected that a manual would be produced and it would cover most categories and levels of benchmarks. Reference to suggested levels could be implied for each benchmarking area, and there would be several levels defined such as minimal, average, above average, excellent and best practice, with a definition in quantitative or qualitative terms against each. It is true that mean, median, midrange, etc. are indication of reference. But cross-references on a number of operational areas are impossible and best practice is difficult to be identified. In addition, due to the sole reliance on traditional statistics, the data base cannot help facility managers determine the criteria to define FM excellence; not to mention the weights among the criteria.

For example, Full Time Equivalent Student Units (FTESU) and GFA are often cross-referenced with cost of energy consumed and security services. These cross-references often cause confusion. Based on the data of the year 2003, among the institutions within CBD of New Zealand, institution number 51 and 68 consumed the least energy per FTESU (3.5 GJ per EFTSU) and GFA (0.35 GJ per m^2) respectively. However, based on this information, a facility manager cannot tell whether institution number 51 or 68 operate better energy management policies. Other critical information is unknown, such as whether they are research universities with engineering faculties, or the proportion of undergraduate to postgraduate students. Further investigation is also difficult because names or contacts of the institutions are not given due to confidentiality.

Other possible errors of the database include:

1. A Singaporean university is considered to be in Australia.
2. 'CBD', 'rural', and 'suburban' are not well defined, yet their effects to institutions in Australia, New Zealand and Hong Kong may be significant.
3. If no data are submitted, the default value is set to zero.
4. Calculations and definitions of FTESU are not given.

It is admitted that some problems mentioned above cannot be solved by collecting and exposing all necessary data and information due to the constraints of individual institution policy. Lack of such information is a common problem for an FM benchmarking group. Best practice cannot be identified and an improvement plan cannot be figured out. A mathematical tool, Data Envelopment Analysis (DEA), has been tested in other sectors and is expected to solve the problem.

5.4 DEA Analysis

The DEA approach is chosen in this case because it:

1. Handles multiple-input and multiple-output situations;
2. Places no restriction on the functional form of the input-output relationship;
3. Requires no predetermined weights for different types of outputs (or inputs);
4. Focuses on revealed best-practice frontiers rather than on central tendency properties of empirical data; and
5. Provides an indication of the levels of improvement needed before an inefficient company could be considered efficient.

The following inputs and outputs are included in this DEA analysis, subject to data availability for specific years.

Table 5.2 Inputs and outputs of the FM operation

FM Inputs	FM Outputs
Total Water Consumption	Customer Satisfaction Rating on (ground) maintenance
Cost of Ground Maintenance	Area Maintained from Central Funds
Staff Salaries & On-costs of campus maintenance unit	
Expenditure on Security Contracts	GFA under Security Patrol
Wages of cleaning staff	Customer Satisfaction Rating on security service
Cleaning Materials cost	Customer Satisfaction Rating on cleaning service
Other Maintenance Expenditure	Customer Satisfaction Rating on parking
	Asset Replacement Value
	EFTSU
	Number of Staff
	Gross Floor Area (Total Campus)
	Useable Floor Area

In this analysis, an input-oriented scenario was assumed. That means outputs were fixed at a constant level and inputs were minimized to produce the given level of outputs. For 1993, only hard data is available. Five institutions are assessed to be inefficient. The results are given in the following table.

Table 5.3 Efficient Input targets by percentage for 1993

Institution	Input-oriented Efficiency (%)	Total Maintenance Expenditure (%)	Total Cleaning Costs (%)	Annual Cost of Energy purchased (%)	Total Grounds Maintenance Expenditure (%)
1	98	0	-15	0	-9
2	90	-34	-10	0	-6
3	98	-20	0	0	-9
4	94	-1	-28	0	0

5	76	-5	0	0	0

Analysis results for 1994 to 2003 may be found in Appendix B. Referring to Table 5.1A, to implement improvement for Charles Stuart University, references are made to Ballarat (2.482), Newcastle (0.233) and South Australia (0.031).

To demonstrate the insufficiency of conventional statistical tools in the application of FM benchmarking, Operation Costs per m^2 (GFA), Operation Cost per EFTSU, and Operation Cost as a percentage of ARV are compared with the DEA efficiency score respectively with the FM data of 2000. Figures are given in Appendix B. The comparison results are illustrated in Figures 5.1, 5.2 and 5.3. Operation cost is the sum of costs on maintenance, refurbishment, cleaning, security and parking.

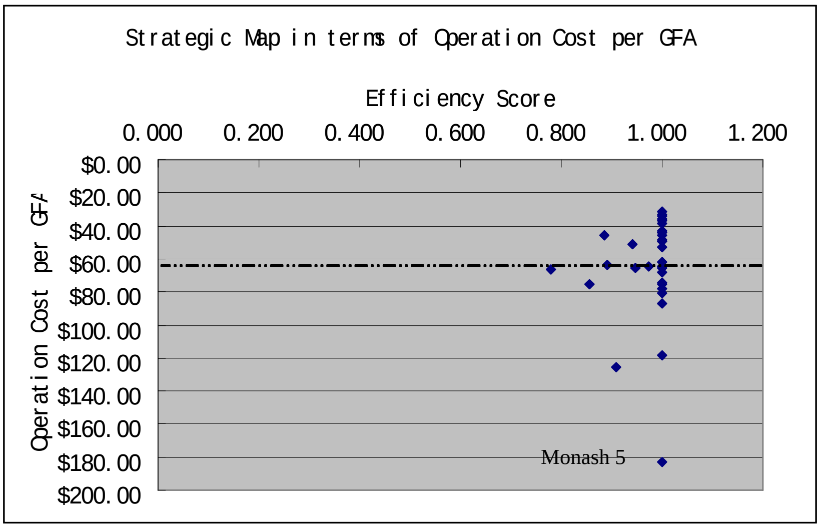

Figure 5.1 Strategic Map in terms of Operation Cost per GFA

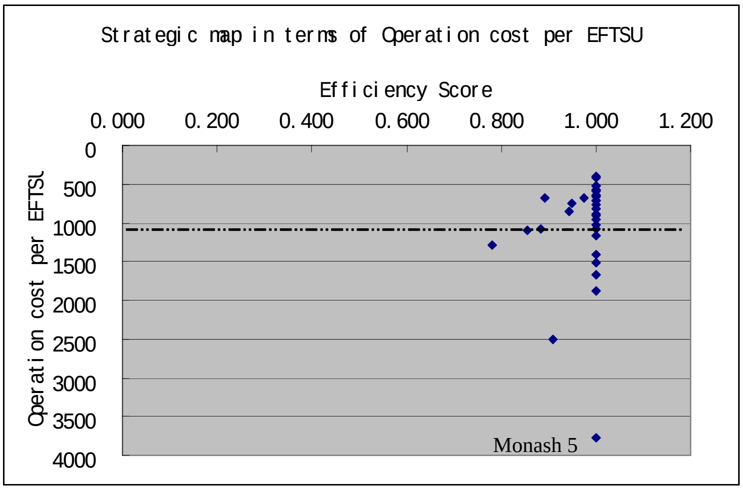

Figure 5.2 Strategic Map in terms of Operation Cost per EFTSU

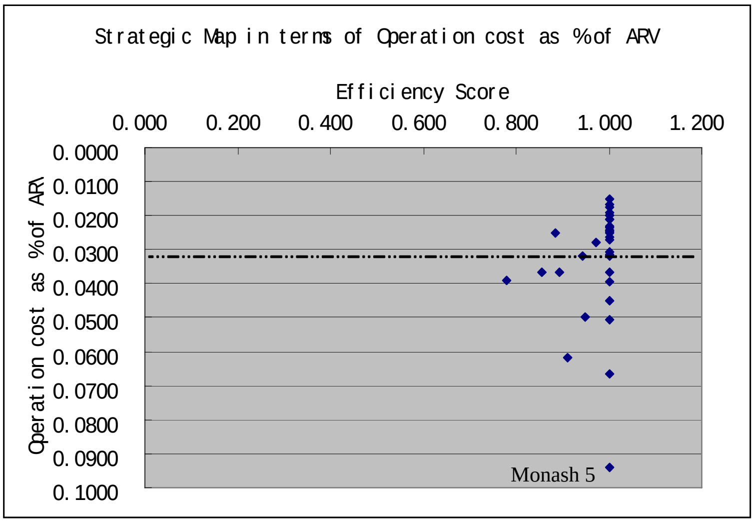

Figure 5.3 Strategic Map in terms of Operation Cost as percentage of ARV

From these results, it appears as if Monash 5, one of the Monash University campuses is the worst performer if operation cost is considered relative to GFA, EFTSU and ARV. This information may in fact be misleading. It is observed that Monash 5 is the second smallest campus in the survey and it serves only 652 EFTSU. For such a small institution, many fixed costs cannot be reduced. However, it is noted that the usable floor area (UFA) as a percentage of GFA of Monash 5 is among the highest, i.e. 76.4%. The average value of UFA as a percentage of GFA is 69.8%. In the DEA analysis, Monash 5 is found to be efficient because it is on the efficient frontier.

Soft data of some institutions was available from year 2000 to 2003. Customer satisfaction covers the FM services of maintenance, refurbishment, cleaning and waste management, security and parking and their ranges for each year are illustrated in table 5.4. Due to the high satisfaction rating given by customers in the survey, all institutions' efficiency score was improved after the customer satisfaction rating was incorporated into the DEA analysis. A Lesser number of institutions are probably another reason for more institutions being assessed as efficient rather than inefficient. The detailed results may be found in Appendix B.

Table 5.4 Ranges and averages of customer satisfaction rating (Likert scale of 1-5)

Year	Average	Range
2000	3.6	2 – 5

2001	3.8	2.8 – 5
2002	3.7	2.9 – 4.4
2003	3.4	2.5 – 4.8

The following are to be noted if soft data is to be incorporated in DEA analysis with hard data:

1. Some soft data, like customer satisfaction, is sometimes interpreted in terms of undesirable measures, e.g. the number of complaints per month. In such cases, a modified DEA model is required. Modifications by mathematical modeling have been dealt with by Zhu, J (2003) and Couder & Verbruggen (2003). Mathematical modeling is not the theme of this research.
2. Soft data like customer satisfaction index is different from hard data. Soft data is usually collected in a range, for example, a Likert scale of 1-5. Hard data often ranges from zero to a number subject to the constraints of other data.
3. Assuming a facility manager would like to find out the cost of improving customer satisfaction through DEA analysis, the input-oriented DEA model used above and in case 1 is not applicable.

Problems 3 and 4 are addressed below.

A level of satisfaction such as 4 or 4.5 of a Likert scale of 1-5 may be set as a target of improvement in the input-oriented DEA model. The question is whether other outputs are to be adjusted to achieve the target and the extent of adjustment. For example, satisfaction on car park services closely relates with the number of car parks available and EFTSU. Therefore it is proposed that references should be made with comparable institutions.

Stated in DEA terms, the problem is targeting resources levels with given outputs. Some target inputs, e.g. operating budgets, are values to be chosen in such a way that the relative efficiency rating meets some desired standard. Hence some inputs are discretionary while others are nondiscretionary.

As proposed by Cook and Zhu (2005), two DEA-based benchmarking models can be applied to deal with this problem:

1. Variable-benchmark model: Each institution is allowed to choose a portion of the benchmark frontier so that the benchmarking performance of the institution is characterized in the most favorable light.
2. Fixed-benchmark model: Each institution is benchmarked against the fixed components from the benchmark frontier. Situations when the same benchmark

should be fixed are likely to occur. For example, management may indicate a specific institution as the fixed benchmark.

The proposed models are tested in this case with the software developed by Cook and Zhu (2005). In the variable-benchmark model, four institutions are chosen as the benchmarks: Wollongong, University of South Australia (UNISA), Griffith 4 and Macquarie. The institutions to be benchmarked are University of Queensland, Curtin, University of Technology Sydney, Edith Cowan University, University of West Australia (UWA) and Victoria University of Technology (VUT). Wollongong is the benchmark in the fixed-benchmark model. The results in 2000 are summarized in the tables 5.5 and 5.6.

Table 5.5 Results of Variable-benchmark model in 2000

Institution	Benchmark Score
UQ	1.09086
Curtin	2.66881
University of Technology Sydney	3.24665
Edith Cowan University	1.37636
UWA	1.32331
VUT	1.38478

Table 5.6 Results of Fixed-benchmark model in 2000

Institution	Fixed-benchmark Efficiency
UQ	0.97974
Curtin	3.46418
University of Technology Sydney	2.38685
Edith Cowan University	1.53876
UWA	1.39096
VUT	2.81819

From the results, we found all benchmarked institutions outperform the best practice except UQ in the fixed-benchmark model. It is also found that modeling transparency is an obvious limitation in the case of the variable-benchmark model.

5.5 Development of the Framework

This chapter solely emphasizes DEA applications for FM benchmarking. As a data-oriented approach for performance evaluation and improvement, DEA is proved to be feasible to deal with both FM soft and hard data. To answer the call from facility managers for a tool to identify FM best practices, DEA is tested for its application on FM operations and customer satisfaction. The main limitation noted in this case is the determination of input and output variables. As noted by Howard and Miller (1993), DEA tends to designate more units as being inefficient as the sample size increases against the number of inputs and outputs. However, increasing the amount of complex data will inhibit the management's focus.

As recommended by Thomas (1994), based on the methodological recommendations from previous DEA research, it was generally suggested that there be a minimum of three times the number of decision making units' (DMU) evaluated compared to the sum of input and output items number in the analysis. But it is noted in FM operation, large range of customers and area served may influence the DEA frontier.

Subject to the objectives of FM benchmarking, DEA may be applied with the following modification:

1. Fixing specific input or output measures in the respective input or output oriented models.
2. Designating variable benchmarks or a fixed benchmark.
3. Setting performance targets.
4. Incorporating expert opinions, as found in case one.

In each modification, efficient and inefficient units can be identified as well as suggested improvement targets and cost involved.

Several issues associated with these modifications to standard DEA analysis remain to be formally and comprehensively explored: One is the feasibility of the resultant Linear Programs which, as it turns out, is not guaranteed under these modifications in some of the DEA models. Other issues include the formal equivalence relation between the modified and standard formulations.

5.6 Test of Hypothesis

Hypothesis 1 postulates the effect of outsourcing and service level specifications development on FM benchmarking. The effect of FM outsourcing increases the difficulty of FM benchmarking, for example, in the comparison of contracting costs and in-house salaries. The comparison is only meaningful if the detailed scale of outsourcing is given. With DEA, the problem may be simplified by incorporating one more input item. But the model transparency is reduced. FM benchmarking and service-level specifications development can be carried out in collaboration.

Hypothesis 2 assumes information & implications deduced from benchmarking study are positively associated with the accomplishments of benchmarking projects. Quality and quantity of information are found to be equally important. By applying recently developed modeling techniques, more information is deduced but the influence on its quality is important, e.g. in DEA application, quality of information is influenced by the number of units for input/output and benchmarking.

Hypotheses 3 and 4 assert facility managers' intuitive or personal experiences are important in the planning of FM improvement. With the collection of data over a few years, a trend may be developed. The success of improvement plan can be adjusted with the support of objective data. Risk is lowered where the improvement plan is executed as part of a portfolio.

Hypothesis 5 submits that popular 'tools' currently used by facility managers, like spectrum diagrams, flowcharts for benchmarking the partner-selection process, scorecards, shaded circles for portraying scorecard-type results, bar charts, and polar graphs (as introduced by Razmi *et al.* (2000)), can only improve clarity in the decision-making process and allow better presentation. Based on case study 2, it is found that the mean as the most popular element of the above mentioned tools cannot offer reliable suggestions for planning FM improvement. Even cross-referencing over a number of items does not help significantly. DEA is proved to be a useful tool.

Hypothesis 6 supposes by taking FM inputs and turning these to outputs, a proposed framework may locate ways of improvement where a detailed map of FM operation system cannot be drawn. It has shown that DEA with given expert opinion from AHP offers guidelines by investigating the source of inefficiencies with reference to the efficiency reference set.

Chapter 6 Cross-case Learning

In this research the choice of case studies has the objective to present two different cases which depict different circumstances that constantly accentuate the point of interest. As pointed out by Eisenhardt (1989),

> "*The cases may be chosen to replicate previous cases or extend emergent theory, or they may be chosen to fill theoretical categories and provide examples of polar types. While the cases may be chosen randomly, random selection is neither necessary, nor even preferable. … given the limited number of cases which can usually be studied, it makes sense to choose cases such as extreme situations and polar types in which the process of interest is transparently observable. Thus, the goal of theoretical sampling is to choose cases which are likely to replicate or extend the emerging theory*."

The appropriateness of the case study is clarified in Table 6.1.

Table 6.1 The suitability of case studies for the requirements of the research

Research requirements	Case study methods applied
To address the lack of research in using mathematical tools on FM benchmarking.	Enables exploration of an area in which few previous studies have carried out, focusing on managerial rather than technical issues: Benbasat *et al.* (1987).
To establish how organizations practise benchmarking to optimize their returns.	Provides a FM benchmarking framework and test with real data. A contemporary phenomenon was studied where the focus is on understanding the dynamic present: Benbasat *et al.* (1987).
To gain an understanding of the practical problems in benchmarking.	Enables the capture of reality, permitting analysis of more variables than possible with other research methods: Galliers and Sutherland (1991).

When selecting the cases for case studies, an approach of information-oriented sampling is applied. The two cases are rich in information and representative.

The subjects in Case 1 are buildings and facilities used for office and operations of communication machines. It is expected that the comprehensive hard and soft data can be organized systematically. The best FM practice can be identified from a defined FM process.

The subjects in Case 2 are buildings and facilities in universities. It is expected that the hard data over 11 years can be put in and be applied in DEA. The most effective FM practice can be identified from different defined FM processes.

The two cases are selected based on discussion and recommendation with FM professionals and academics in local and international conferences.
It is the intention of the research that by looking into the two cases, common FM data can be examined in different ways. When a pattern from one case is corroborated by the evidence from another, the finding is stronger. When evidence conflicts, deeper probing of the differences is necessary to identify the cause.

6.1 Contrasting the Two Cases

The two cases presented in the last two chapters are different in location, industry, customer type, scale, years of data or information collected and type of benchmarking. In case one, the facility manager of Company ABC manages all the fourteen buildings in the survey and collects their data. In case two, the facility manager of the individual institution does not take any active role in the assessment of other institutions' FM services and data collection. Nevertheless, both projects have a number of common FM objectives such as a reduction of operation costs and improvements in customer satisfaction. Other useful benchmarks are also common such as seeking operation efficiencies. However, the scales of the two surveys are different. The first case study refers to a single/ occupier participates in benchmarking a portfolio of properties whose function may vary. The second case study refers to an annual benchmarking survey involving a wider range of tertiary institutions located in Australia.

In the first case study, with the data from the customer satisfaction survey of Company ABC, analysis indicates that the relative weights among different FM services can be found with regression analysis. The results show high consistency among the relative weights for different FM services with respect to general FM customer satisfaction. The relative weights found are useful in resource allocation in the planning of FM services. They also serve as a good reference when alerting clients of areas of improvement. For example, FM clients should be alerted about security of personnel issues that impact the quality of FM services. In the second case study, similar types of data and information of customer satisfaction were not available for analysis. If the same survey and investigation is carried out in the second case, the problems are:

1. The independent variables may not be useful in predicting the dependent variable.

The cultural difference across the countries included in the survey may cast doubt when comparing the results. For example, customer satisfaction surveys in Hong Kong may be incomparable to the surveys in Australia, New Zealand and Singapore. The survey tool for Hong Kong may also be required translation into Chinese. The relative applicability of the survey tool should therefore be tested as in non-English-speaking countries.

2. Customers of institutions include visitors, employees, students and occasion visitors. Most internal customers served by FM departments of commercial organizations are employees. Hence, analysis of the internal and external customers' satisfaction in case two is more complicated when compared to the internal customers' satisfaction analysis in case one.

TEFMA may investigate the linkages among customer service quality, customer satisfaction and long-term 'business success' before application of regression analysis is attempted. Useful references include the American Customer Satisfaction Index (ACSI) and the European Customer Service Index (ECSI). These two customer satisfaction indices (CSIs) function as intangible economic indicators used to monitor the financial viability of companies, industries, and international trade unions (Fornell (2001)).

Analytic Hierarchy Process (AHP) with the Delphi method is applied in case one to analyze the executives' comprehension on the relative importance of FM items with reference to general customer satisfaction. The results were compared with the results of linear regression. Significant differences were noted. In general, it is acknowledged that customer satisfaction measurement is a post-consumption assessment by a user after a product or service has been gained (Yuksel and Rimmington (1998)). It is associated with the identification of customer expectations versus what they actually experienced. This is also known as the confirmation and disconfirmation of expectations approach. In other words, a facility manager can satisfy his customers by maneuvering customer expectation or adjusting the service quality. AHP and linear regression can help him measure the difference.

In case two, customer expectation and satisfaction information of other institutions enhance the service provided to external customers. It is expected that external benchmarking will become more important, especially for FM services applied to the convention, hotel, premium office complexes etc.

In case one, AHP is applied to extract expert opinion on changes of FM costs. The expert opinion can then be interpreted as relative weights on DEA analysis. In large scale external benchmarking as in case two, expert opinion is suggested to be incorporated with FM information of the benchmarking group by the facility manager of an individual institution. For example, institutions included in the benchmarking group are located in Australia, Hong Kong, Singapore and New Zealand. These countries have their own regional factors to be considered. Some examples, as suggested by MacCarthy & Atthirawong (1993), are costs, infrastructure, labour characteristics, political and economic factors. These examples are made up of quality of labour force, existence of transportation modes, quality and reliability of transportation modes, availability of labour, quality and reliability of utilities, wage rates, motivation of workers, telecommunication systems, record of government stability and industrial relations laws. They are difficult to be considered by mathematical modeling. In both cases, they are collectively reflected by customer satisfactions. For instance, customer satisfaction of car park services is closely related to the existence of transportation options, the number of car parks in the neighbours and charges.

In case two, the DEA model, with the following modification, is able to analyze FM efficiency in different scenarios.

1. Fixed and variable benchmark model
2. Performance target-setting
3. Weighting setting
4. Measure-specific model

These modifications can be made and applied with the information and data in case one subject to the constraints of available participants in the benchmarking group and number of inputs/outputs. As recommended by Thomas (1994), based on the methodological recommendations from previous DEA researches, it was generally suggested that there be a minimum of three times the number of Decision Making Units' (DMU) evaluated compared to the sum of input and output items number in the analysis.

Trend analysis cannot be made in both cases because the lack of data in case one. In case two, it cannot be carried out because of the constraints of available data.

6.2 Application of the Proposed Framework

In both cases, we treated the framework as a machine. A suitable quantity and quality of data is transformed into a designated format as inputs. The framework then analyzes the inputs and produces the outputs, like an efficiency score and a reference set for improvement. Apart from planning FM improvement, the proposed framework is useful in the process of decision making related to FM issues. An example is given below.

With reference to Pandey & Bansal (2003), an FM outsourcing decision is structured as a four-level decision hierarchy:

1. The overall goal is determined: extract business-value from FM outsourcing.
2. Three objectives are identified with respect to the goal of using outsourcing to:
    a) Help solve the immediate FM business problems
    b) Improve FM business
    c) Transform FM business

3. With respect to each of the above objective, the following activities are decided:
    a) Get access to better technology
    b) Cut costs
    c) Increase focus on core-competencies
    d) Improve FM skills of personnel
    e) Change FM perceptions of the organization
    f) Reduce risks
    g) Create FM-based new lines of business
4. Four general FM contract types, as outsourcing methodologies, are listed:
    a) Insourcing: The organization lets its own FM department take responsibility.
    b) Value-added outsourcing: The organization enters into a close and strategic alliance with the supplier.
    c) Short-term outsourcing: The activity gets outsourced for a short period.
    d) Long-term outsourcing: The activity gets outsourced to a vendor for a long period.

Once the details of the above four levels hierarchy are decided, the proposed FM benchmarking framework can be applied to assist the facility manager to choose a contract type. A facility manager can decide a suitable FM outsourcing plan for his organization with reference to the efficiency scores of other similar organizations which practise insourcing, value-added outsourcing, short-term outsourcing and long-term outsourcing. The respective advantages and disadvantages of a particular contract can be investigated with the information of peers in the benchmarking group.

6.3 Contributions of this Cross-case Learning

This cross-case learning contributes to this research in two arenas:

1. It is the intention of this research to develop and demonstrate the applicability of the proposed decision making tools. The generic difference of the two cases should be noted, e.g. location and cultural factors in the interpretation of FM data and information of cross-country survey, e.g. customer satisfaction and expectation.
2. The two cases offer different domains of FM data. Case one provides all the necessary data of a single year to test all the three tools. Though data of case two is not enough for a trend analysis, the amount of data over eleven years is sufficient to test some DEA modifications.

Chapter 7 Conclusions

In this research, the practical problems of organizing, interpreting FM data and extracting information from the data are set out and discussed. Integration of soft and hard data of FM is identified as a source of problems from two case studies. Implementation of FM improvement measures requires clear and achievable benchmarks. With reference to benchmarking literature from other fields, it is shown that mathematical tools are often applied in the determination of benchmarks and performance measurement. The tools are applied and demonstrated how to assist facility managers to develop a clear picture of their facility's operation and customers' demands.

7.1 Summary of Hypothesis Testing

The study used and compared two case studies to examine FM as a service operation with the proposed benchmarking tools fully tested. It is put forward that a decision making framework (as proposed in Chapter 3), which is composed of AHP, DEA and linear regression analysis, combines the strengths of the three tools. In addition, some principles for FM data interpretation and organization are discussed, targeting the acquisition of a maximum amount of knowledge for FM business improvement. The variety and richness of the data in the two cases and analysis of the results strongly supports the usefulness of applying the tools in FM benchmarking. This represents the first conclusion of this study.
As reported in Chapters 4, 5 and 6, the case studies enabled seven hypotheses to be tested. A summary of these test results is shown in Table 7.1.

Table 7.1 Summary of Hypothesis Testing

	Internal Benchmarking study	External Benchmarking study (Data source: benchmarking group)
Hypothesis 1. Outsourcing, specifications development and other common FM practices pose a paradox for FM benchmarking. For example, outsourcing agreements often cover service charges based on area and service levels, which frequently involve ambiguity, Rees 1999. DEA & AHP can be applied to offer a clearer picture.	Not supported	Not supported.
Hypothesis 2. The amounts and dimensions of relevant information deduced from the benchmarking study are positively associated with the accomplishments of benchmarking projects.	Supported	Weakly supported.
Hypothesis 3. Periodic benchmarking or performance measurements are good tools of indications, especially when wrong steps are just made.	Not Supported	Weakly supported.
Hypothesis 4. DEA and AHP can offer more guidelines for many FM improvement policies. Risks of improvements' executions can be reduced.	Strongly supported	Strongly supported for DEA application.
Hypothesis 5. Popular 'tools' currently used by facility managers can only improve clarity in the decision-making process and allow better presentation. They cannot perform in-depth analysis for FM benchmarking for achieving the best among peers.	Strongly supported	Strongly supported.
Hypothesis 6. By taking FM inputs and turning these to outputs, the proposed benchmarking tools can locate ways of improvement. It can give facility managers guidelines by investigating the possible source of inefficiencies with reference to the efficiency reference set.	Strongly supported	Strongly supported.

7.2 Contributions of this study

Since the early 1990s, research in FM and Benchmarking has stressed the importance of objective measurement based on hard and soft data (Kincaid (1994)). This research presents a method which shows how the data could be integrated for improvement execution.

As a process of service operations, facility management is interpreted as an input-output system which can be assessed by DEA in terms of productivity. As many services industries, customer satisfaction is an important factor within the input-output system.

Facility managers and their customers have similar assessment criteria on FM performance. But the criteria are often with different weight in the two groups. Facility managers are often unprepared to plan for and react to uncertainty due to the difference in FM assessment criteria. In the first case study, AHP is applied and successfully overcomes the hurdles of FM information analysis and then combination of the information by a unique pair-wise comparison system of AHP. The system guides facility managers to incorporate all relevant information. In the same case study, regression analysis is used to optimize resources of an FM department by adapting to variables, and manage the constraints inherent in budgeting process.

These explain the need for a unique framework for facility management benchmarking. Based on the case studies, this research found that the framework could work with soft and hard data of facility management with clear indications for improvements. Contributions of this study include:

1. Integration of the knowledge of decision tools with facility management benchmarking.
2. Comprehensive design principles for a facility management benchmarking framework targeted to the acquisition of a maximum amount of knowledge for FM business improvement.
3. Assistance to facility managers to develop a clear picture of their facility operation and customers' demands with the proposed tools.

7.3 Study Limitations

1. Data collection was limited to facility management units in Hong Kong and the South Pacific region.
2. The data collected in the two case studies is based on a retrospective re-creation of FM services planning and its execution from available documentation and

from the recollections of project participants. The retrospective nature is justifiable because benchmarking means learning from the results.

3. Due to data availability, tests on the proposed tools with trend analysis are not possible in this study.
4. As illustrated in Case Study Two, FM units in the same industry might have very different operation and might be difficult to be analyzed with respect to its performance.

7.4 Implications for Further Research

Other strategic measurements can be attempted. A good reference is Kaplan and Norton scorecard model. However, the structuring of the scorecard model's four arms into inputs and outputs domain of DEA is the first hurdle.

The design principles of FM benchmarking model discussed in this study are largely based on theories of operations research. They are easy to be redeveloped for research on computer methods and systems for network-based evaluation engines.

From Case Study Two, it is noted that when benchmarking against competitors, the best approach is to look at trends in FM parameters rather than a point in time. As mentioned above, to do so, a consistent FM benchmarking survey with consistent support from participants is necessary. It is substantially more works in the stage of planning and analyzing. But it will give a more reliable picture of how the companies are performing relative to one another.

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Appendix

Appendix A

The statistical figures of overall satisfaction levels and the 6 chosen items (in the scale of 1-5, where 1 stands for 'very poor' and 5 stands for 'very good') are list below:

Table 4.1A Summary of survey results

	Overall Satisfaction	Security Comfort Level	Attitude of Guard	Cleanliness: Common Areas	Cleanliness: Office Areas	Cleanliness: Pantry	Cleanliness: Washroom
Building 1	3.50	3.67	4.06	3.86	3.47	3.55	**2.81**
Building 2	3.70	3.72	3.90	3.81	3.39	3.21	3.45
Building 3	4.16	3.94	3.90	3.58	3.81	3.69	3.53
Building 4	3.84	4.06	4.14	4.14	4.00	3.81	3.61
Building 5	3.59	4.08	4.49	3.77	3.21	3.05	**2.44**
Building 6	3.82	3.68	4.00	3.68	3.60	3.61	3.66
Building 7	3.79	3.63	3.90	3.78	3.21	3.22	**2.93**
Building 8	3.67	3.63	4.07	3.75	3.49	3.27	**2.97**
Building 9	4.28	3.99	4.14	4.39	4.00	3.74	3.63
Building 10	4.02	3.92	4.35	3.94	3.60	3.50	3.43
Building 11	3.60	3.41	3.69	3.79	3.53	3.58	3.40
Building 12	3.69	3.38	4.09	3.99	3.60	3.55	3.14
Building 13	3.79	3.63	3.88	3.89	3.73	3.67	3.46
Building 14	3.58	3.90	4.28	3.78	3.29	3.07	3.18

Table 4.2A Statistics of Building 1 customers' perceptions on the FM services

	Overall Satisfaction	Security Comfort Level	Attitude of Guard	Cleanliness Common Areas	Cleanliness Office Areas	Cleanliness Pantry	Cleanliness Washroom
Average	3.5000	3.6701	4.0612	3.8614	3.4653	3.5545	2.8119
Mode	4	4	4	4	4	4	3
Median	4	4	4	4	4	4	3
Number of Response	96	97	98	101	101	101	101
Standard deviation	0.7947	0.6245	0.5337	0.5836	0.7690	0.7277	1.0268

Table 4.3A Statistics of Building 2 customers' perceptions on the FM services

	Overall Satisfaction	Security Comfort Level	Attitude of Guard	Cleanliness Common Areas	Cleanliness Office Areas	Cleanliness Pantry	Cleanliness Washroom
Average	3.7027	3.7222	3.9041	3.8108	3.3929	3.2143	3.4459
Mode	4	4	4	4	4	3	3
Median	4	4	4	4	4	3	3
Number of Response	74	72	73	74	28	28	74
Standard deviation	0.7163	0.6548	0.6273	0.6553	0.9165	0.7868	0.6441

Table 4.4A Statistics of Building 3 customers' perceptions on the FM services

	Overall Satisfaction	Security Comfort Level	Attitude of Guard	Cleanliness Common Areas	Cleanliness Office Areas	Cleanliness Pantry	Cleanliness Washroom
Average	4.1579	3.9412	3.9000	3.5789	3.8125	3.6875	3.5263
Mode	4	4	4	4	4	4	4
Median	4	4	4	4	4	4	4
Number of Response	19	17	10	19	16	16	19
Standard deviation	0.7647	0.5557	0.5676	0.8377	0.7500	0.7042	0.6118

Table 4.5A Statistics of Building 4 customers' perceptions on the FM services

	Overall Satisfaction	Security Comfort Level	Attitude of Guard	Cleanliness Common Areas	Cleanliness Office Areas	Cleanliness Pantry	Cleanliness Washroom
Average	3.8413	4.0645	4.1429	4.1429	4.0000	3.8077	3.6129
Mode	4	4	4	4	4	4	3
Median	4	4	4	4	4	4	4
Number of Response	63	62	63	63	29	26	62
Standard deviation	0.6012	0.6496	0.7152	0.6923	0.8864	0.8010	0.9118

Table 4.6A Statistics of Building 5 customers' perceptions on the FM services

	Overall Satisfaction	Security Comfort Level	Attitude of Guard	Cleanliness Common Areas	Cleanliness Office Areas	Cleanliness Pantry	Cleanliness Washroom
Average	3.5946	4.0769	4.4872	3.7692	3.2051	3.0513	2.4359
Mode	4	4	5	4	3	3	3
Median	4	4	5	4	3	3	3
Number of Response	37	39	39	39	39	39	39
Standard deviation	0.5990	0.5324	0.5559	0.6267	0.8006	0.7930	0.8206

Table 4.7A Statistics of Building 6 customers' perceptions on the FM services

	Overall Satisfaction	Security Comfort Level	Attitude of Guard	Cleanliness Common Areas	Cleanliness Office Areas	Cleanliness Pantry	Cleanliness Washroom
Average	3.8182	3.6765	4.0000	3.6765	3.6000	3.6111	3.6563
Mode	4	4	4	4	4	4	4
Median	4	4	4	4	4	4	4
Number of Response	33	34	34	34	30	18	32
Standard deviation	0.5276	0.6382	0.2462	0.5888	0.4983	0.5016	0.6016

Table 4.8A Statistics of Building 7 customers' perceptions on the FM services

	Overall Satisfaction	Security Comfort Level	Attitude of Guard	Cleanliness Common Areas	Cleanliness Office Areas	Cleanliness Pantry	Cleanliness Washroom
Average	3.7910	3.6286	3.9000	3.7826	3.2131	3.2203	2.9286
Mode	4	4	4	4	3	3	3
Median	4	4	4	4	3	3	3
Number of Response	67	70	70	69	61	59	70
Standard deviation	0.5651	0.8195	0.8538	0.6613	0.8586	0.7208	0.9679

Table 4.9A Statistics of Building 8 customers' perceptions on the FM services

	Overall Satisfaction	Security Comfort Level	Attitude of Guard	Cleanliness Common Areas	Cleanliness Office Areas	Cleanliness Pantry	Cleanliness Washroom
Average	3.6667	3.6347	4.0714	3.7500	3.4930	3.2714	2.9697
Mode	4	4	4	4	4	3	3
Median	4	4	4	4	4	3	3
Number of Response	165	167	168	168	142	140	165
Standard deviation	0.7269	0.6798	0.5951	0.6166	0.6815	0.7666	0.8655

Table 4.10A Statistics of Building 9 customers' perceptions on the FM services

	Overall Satisfaction	Security Comfort Level	Attitude of Guard	Cleanliness Common Areas	Cleanliness Office Areas	Cleanliness Pantry	Cleanliness Washroom
Average	4.2842	3.9947	4.1421	4.3895	4.0000	3.7436	3.6330
Mode	4	4	4	5	4	4	4
Median	4	4	4	5	4	4	4
Number of Response	190	190	190	190	183	156	188
Standard deviation	0.7298	0.4770	0.4779	0.7460	0.7983	0.7609	0.8198

Table 4.11A Statistics of Building 10 customers' perceptions on the FM services

	Overall Satisfaction	Security Comfort Level	Attitude of Guard	Cleanliness Common Areas	Cleanliness Office Areas	Cleanliness Pantry	Cleanliness Washroom
Average	4.0208	3.9184	4.3542	3.9388	3.6000	3.5000	3.4286
Mode	4	4	5	4	3	3	3
Median	4	4	4.5	4	3.5	3	3
Number of Response	48	49	48	49	40	38	49
Standard deviation	0.6681	0.7023	0.7290	0.5556	0.7442	0.6877	0.6770

Table 4.12A Statistics of Building 11 customers' perceptions on the FM services

	Overall Satisfaction	Security Comfort Level	Attitude of Guard	Cleanliness Common Areas	Cleanliness Office Areas	Cleanliness Pantry	Cleanliness Washroom
Average	3.6042	3.4063	3.6947	3.7938	3.5333	3.5833	3.4043
Mode	4	4	4	4	4	4	4
Median	4	4	4	4	4	4	4
Number of Response	96	96	95	97	60	60	94
Standard deviation	0.6237	0.8408	0.6535	0.6605	0.7912	0.6187	0.8838

Table 4.13A Statistics of Building 12 customers' perceptions on the FM services

	Overall Satisfaction	Security Comfort Level	Attitude of Guard	Cleanliness Common Areas	Cleanliness Office Areas	Cleanliness Pantry	Cleanliness Washroom
Average	3.6861	3.3826	4.0873	3.9913	3.5982	3.5493	3.1354
Mode	4	4	4	4	4	4	3
Median	4	4	4	4	4	4	3
Number of Response	223	230	229	231	219	213	229
Standard deviation	0.6508	0.9069	0.5551	0.6460	0.6727	0.7227	0.9885

Table 4.14A Statistics of Building 13 customers' perceptions on the FM services

	Overall Satisfaction	Security Comfort Level	Attitude of Guard	Cleanliness Common Areas	Cleanliness Office Areas	Cleanliness Pantry	Cleanliness Washroom
Average	3.7879	3.6288	3.8779	3.8864	3.7328	3.6667	3.4615
Mode	4	4	4	4	4	4	4
Median	4	4	4	4	4	4	4
Number of Response	132	132	131	132	131	132	130
Standard deviation	0.6057	0.8046	0.5410	0.5615	0.5794	0.6137	0.7061

Table 4.15A Statistics of Building 14 customers' perceptions on the FM services

	Overall Satisfaction	Security Comfort Level	Attitude of Guard	Cleanliness Common Areas	Cleanliness Office Areas	Cleanliness Pantry	Cleanliness Washroom
Average	3.5784	3.9038	4.2762	3.7767	3.2935	3.0659	3.1765
Mode	4	4	4	4	4	4	3
Median	4	4	4	4	3	3	3
Number of Response	102	104	105	103	92	91	102
Standard deviation	0.6515	0.6156	0.5964	0.5762	0.9203	1.0414	0.8834

Table 4.16A DEA analysis results: Technical buildings without adjustment on input weights

Inputs	**Outputs**
Total cleaning cost	Equipment area sq.ft.
Total Maintenance Fee	Office area sq.ft.
Energy Use (kWh)	Number of staff
Total security cost	Satisfaction on Security
	Satisfaction on Guard Attitude
	Satisfaction on Common Areas Cleanliness
	Satisfaction on Office Cleanliness
	Satisfaction on Pantry Cleanliness
	Satisfaction on Washroom Cleanliness

DMU No.	DMU Name	Input-Oriented CRS Efficiency	Σλ	RTS	**Benchmarks**					
1	Building 4	1.00000	1.000	Constant	1.000	Building 4				
2	Building 6	1.00000	1.000	Constant	1.000	Building 6				
3	Building 7	1.00000	1.000	Constant	1.000	Building 7				
4	Building 8	1.00000	1.000	Constant	1.000	Building 8				
5	Building 9	1.00000	1.000	Constant	1.000	Building 9				
6	Building 10	1.00000	1.000	Constant	1.000	Building 10				
7	Building 11	1.00000	1.000	Constant	1.000	Building 11				
8	Building 13	0.89003	1.011	Decreasing	0.164	Building 4	0.251	Building 9	0.596	Building 11
9	Building 14	0.89045	1.238	Decreasing	0.509	Building 7	0.302	Building 8	0.427	Building 10

Notes: To implement improvement for Building 13, references are made to Building 4 (0.164), Building 9 (0.251), Building 11 (0.596).

Table 4.17A DEA analysis results: Technical buildings with adjustments on input weights

Inputs	Weights
Total cleaning cost	1
Total Maintenance Fee	1
Energy Use (kWh)	2
Total security cost	1

Outputs
Equipment area sq.ft.
Office area sq.ft.
Number of staff
Satisfaction on Security
Satisfaction on Guard Attitude
Satisfaction on Common Areas Cleanliness
Satisfaction on Office Cleanliness
Satisfaction on Pantry Cleanliness
Satisfaction on Washroom Cleanliness

		Input-Oriented CRS	**Input Changes**		
DMU No.	DMU Name	Restricted PS Efficiency	**Total cleaning cost**	**Total Maintenance Fee (security sys)**	**Energy Use (kWh)**
1	Building 4	1.00000	1.00000	1.00000	1.00000
2	Building 6	1.00000	1.00000	1.00000	1.00000
3	Building 7	1.00000	1.00000	1.00000	1.00000
4	Building 8	1.00000	1.00000	1.00000	1.00000
5	Building 9	1.00000	1.00000	1.00000	1.00000
6	Building 10	1.00000	1.00000	1.00000	1.00000
7	Building 11	1.00000	1.00000	1.00000	1.00000
8	Building 13	0.61697	0.92333	0.38382	0.68397
9	Building 14	0.79189	0.89683	0.80275	0.87184

Notes: Relative efficiency of Building 13 and Building 14 can be improved by adjusting the inputs.

Appendix B

Table 5.1A DEA analysis results: 1993

Inputs	Outputs
Total Maintenance expenditure (AUD)	Gross Floor Area (m2)
Total Cleaning Costs (AUD)	Useable Floor Area (m2)
Annual cost of Energy purchased (AUD)	EFTSU
Total Grounds Maintenance Expenditure (A	Area Maintained from Central Funds (m2)
	Area Cleaned from Central Funds (m2)
	Total GFA serviced with Energy (m2)
	Asset Replacement Value (AUD)

DMU No.	DMU Name	Input-Oriented CRS Efficiency	Σλ	RTS	Benchmarks					
1	Australian National University	1.00000	1.000	Constant	1.000	Australian National University				
2	Charles Stuart University	0.98032	2.746	Decreasing	2.482	University of Ballarat	0.233	University of Newcastle	0.031	University of South Australia
3	Flinders University	1.00000	1.000	Constant	1.000	Flinders University				
4	Griffith University	0.90297	1.205	Decreasing	0.455	University of South Australia	0.749	University of Southern Queensland		
5	La Trobe University	1.00000	1.000	Constant	1.000	La Trobe University				
6	Macquarie University	1.00000	1.000	Constant	1.000	Macquarie University				
7	Monash University - Clayton	0.97835	2.235	Decreasing	1.783	University of Ballarat	0.367	University of Melbourne	0.085	University of South Australia
8	Monash University - Gippsland	1.00000	1.000	Constant	1.000	Monash University - Gippsland				
9	Murdoch University	1.00000	1.000	Constant	1.000	Murdoch University				
10	QUT	0.93916	2.879	Decreasing	0.856	Macquarie University	1.696	University of Ballarat	0.327	University of Southern Queensland
11	University of Adelaide	1.00000	1.000	Constant	1.000	University of Adelaide				
12	University of Ballarat	1.00000	1.000	Constant	1.000	University of Ballarat				
13	University of Melbourne	1.00000	1.000	Constant	1.000	University of Melbourne				
14	University of Newcastle	1.00000	1.000	Constant	1.000	University of Newcastle				
15	University of Otago	1.00000	1.000	Constant	1.000	University of Otago				
16	University of Queensland	0.75973	2.920	Decreasing	2.202	University of Ballarat	0.288	University of Melbourne	0.430	University of South Australia
17	University of South Australia	1.00000	1.000	Constant	1.000	University of South Australia				
18	University of Southern Queenslan	1.00000	1.000	Constant	1.000	University of Southern Queensland				
19	University of Sydney	1.00000	1.000	Constant	1.000	University of Sydney				
20	University of Waikato	1.00000	1.000	Constant	1.000	University of Waikato				
21	University of Western Australia	1.00000	1.000	Constant	1.000	University of Western Australia				
22	University of Western Sydney	1.00000	1.000	Constant	1.000	University of Western Sydney				

Notes: to implement improvement for Charles Stuart University, references are made to Ballarat (2.482), Newcastle (0.233) and South Australia (0.031)

Table 5.2A DEA analysis results: 1994

Inputs	**Outputs**
Total Maintenance expenditure (AUD)	Gross Floor Area (m2)
Total Cleaning Costs (AUD)	Useable Floor Area (m2)
Total Refurbishment costs (AUD)	EFTSU
Total security cost (AUD)	Area Maintained from Central Funds (m2)
Total cost of parking systems (AUD)	Area Cleaned from Central Funds (m2)

DMU No.	DMU Name	Input-Oriented CRS Efficiency	**Σλ**	RTS	**Benchmarks**									
1	Edith Cowan University	1.00000	1.000	Constant	1.000	Edith Cowan University								
2	Griffith University	0.89080	1.574	Decreasing	0.016	Edith Cowan University	0.491	James Cook Unive	0.187	La Trobe University	0.881	USQ		
3	James Cook University	1.00000	1.000	Constant	1.000	James Cook University								
4	La Trobe University	1.00000	1.000	Constant	1.000	La Trobe University								
5	Macquarie University	1.00000	1.000	Constant	1.000	Macquarie University								
6	Melbourne University	1.00000	1.000	Constant	1.000	Melbourne University								
7	Monash (Clayton)	0.99590	2.214	Decreasing	0.241	Edith Cowan University	0.190	La Trobe Univers	0.313	Melbourne University	1.399	Monash (Gippsland	0.072	University of Newcastle
8	Monash (Gippsland)	1.00000	1.000	Constant	1.000	Monash (Gippsland)								
9	QUT	1.00000	1.000	Constant	1.000	QUT								
10	University of Sydney	1.00000	1.000	Constant	1.000	University of Sydney								
11	University of South Australia	1.00000	1.000	Constant	1.000	University of South Australia								
12	University of Queensland	0.77856	1.818	Decreasing	0.108	Edith Cowan University	0.742	James Cook Unive	0.683	La Trobe University	0.264	Melbourne Univers	0.021	University of Newcastle
13	USQ	1.00000	1.000	Constant	1.000	USQ								
14	University of Newcastle	1.00000	1.000	Constant	1.000	University of Newcastle								

Notes: to implement improvement for Griffith University, references are made to Edith Cowan (0.016), James Cook (0.491), La Trobe (0.187) and USQ (0.881)

Table 5.3A DEA analysis results: 1995

Inputs	Outputs
Total Maintenance expenditure (AUD)	Gross Floor Area (m2)
Total Cleaning Costs (AUD)	Useable Floor Area (m2)
Annual cost of Energy purchased (AUD)	EFTSU
Total security cost (AUD)	Area Maintained from Central Funds (m2)
Total cost of parking systems (AUD)	Area Cleaned from Central Funds (m2)
	Total GFA serviced with Energy (m2)
	GFA under Security Patrol (m2)
	Total Number of Parking Spaces available
	Asset Replacement Value (AUD)

DMU No.	DMU Name	Input-Oriented CRS Efficiency	Σλ	RTS	Benchmarks							
1	Australian National University	1.00000	1.000	Constant	1.000	Australian National University						
2	Edith Cowan University	1.00000	1.000	Constant	1.000	Edith Cowan University						
3	Griffith University	1.00000	1.000	Constant	1.000	Griffith University						
4	James Cook University of North Q	1.00000	1.000	Constant	1.000	James Cook University of North Qld						
5	LaTrobe Uni (Bundoora/Met.Campus	1.00000	1.000	Constant	1.000	LaTrobe Uni (Bundoora/Met.Campuses)						
6	Macquarie University	1.00000	1.000	Constant	1.000	Macquarie University						
7	Monash (Clayton)	1.00000	1.000	Constant	1.000	Monash (Clayton)						
8	Murdoch University	1.00000	1.000	Constant	1.000	Murdoch University						
9	Northern Territory University	1.00000	1.000	Constant	1.000	Northern Territory University						
10	Swinburne University of Technolo	1.00000	1.000	Constant	1.000	Swinburne University of Technology						
11	The Flinders University of SA	1.00000	1.000	Constant	1.000	The Flinders University of SA						
12	The Uni of Adelaide (North Terra	1.00000	1.000	Constant	1.000	The Uni of Adelaide (North Terrace)						
13	The University of Melbourne	1.00000	1.000	Constant	1.000	The University of Melbourne						
14	The University of New South Wale	1.00000	1.000	Constant	1.000	The University of New South Wales						
15	The Uni of Newcastle (Callaghan)	1.00000	1.000	Constant	1.000	The Uni of Newcastle (Callaghan)						
16	The University of Queensland	0.86800	2.247	Decreasing	0.801	The Flinders University of SA	1.241	The Uni of Adela	0.167	e University of Sydney	0.039	Uni of Technology Sydney
17	The University of Southern Queen	1.00000	1.000	Constant	1.000	The University of Southern Queensland						
18	The University of Sydney	1.00000	1.000	Constant	1.000	The University of Sydney						
19	The University of Western Austra	1.00000	1.000	Constant	1.000	The University of Western Australia						
20	University of South Australia	1.00000	1.000	Constant	1.000	University of South Australia						
21	Uni of Technology Sydney	1.00000	1.000	Constant	1.000	Uni of Technology Sydney						

Notes: to implement improvement for University of Queensland, references are made to Flinders (0.801), Adelaide (1.241), Sydney (0.167) and Technology Sydney (0.039)

Table 5.4A DEA analysis results: 1996

Inputs	**Outputs**
Total Cleaning Costs (AUD)	Gross Floor Area (m2)
Annual cost of Energy purchased (AUD)	Useable Floor Area (m2)
Total security cost (AUD)	EFTSU
Total cost of parking systems (AUD)	Area Maintained from Central Funds (m2)
Total Grounds Maintenance Expenditure (A	Area Cleaned from Central Funds (m2)
Cost of purchasing water	Asset Replacement Value ($)
	Total GFA serviced with Energy (m2)
	Total GFA under security control (m2)
	Number of parking place available
	Ground Area Maintained from Central Funds (m2)

DMU No.	DMU Name	Input-Oriented CRS Efficiency	Σλ	RTS	Benchmarks									
1	Deakin University	1.00000	1.000	Constant	1.000	Deakin University								
2	Edith Cowan University	1.00000	1.000	Constant	1.000	Edith Cowan University								
3	Griffith University	0.95091	2.460	Decreasing	0.011	Deakin University	0.033	Monash (Clayton)	0.478	The Uni of Adelaide (Waite)	1.733	The University of	0.205	University of South Australia
4	LaTrobe Uni (Bundoora/Met.Campus	1.00000	1.000	Constant	1.000	LaTrobe Uni (Bundoora/Met.Campuses)								
5	Macquarie University	1.00000	1.000	Constant	1.000	Macquarie University								
6	Monash (Clayton)	1.00000	1.000	Constant	1.000	Monash (Clayton)								
7	Murdoch University	1.00000	1.000	Constant	1.000	Murdoch University								
8	The Uni of Adelaide (North Terra	1.00000	1.000	Constant	1.000	The Uni of Adelaide (North Terrace)								
9	The Uni of Adelaide (Waite)	1.00000	1.000	Constant	1.000	The Uni of Adelaide (Waite)								
10	The Uni of Newcastle (Callaghan)	1.00000	1.000	Constant	1.000	The Uni of Newcastle (Callaghan)								
11	The University of New South Wale	1.00000	1.000	Constant	1.000	The University of New South Wales								
12	The University of Queensland	0.78404	1.491	Decreasing	0.636	LaTrobe Uni (Bundoora/Met.Campus	0.133	Monash (Clayton)	0.052	The Uni of Adelaide (North T	0.086	The University of	0.584	University of South Australia
13	The University of Southern Queen	1.00000	1.000	Constant	1.000	The University of Southern Queensland								
14	The University of Sydney	1.00000	1.000	Constant	1.000	The University of Sydney								
15	The University of Western Austra	0.94951	1.324	Decreasing	0.069	Edith Cowan University	0.134	Monash (Clayton)	0.405	Murdoch University	0.321	The University of	0.273	The University of Sy	0.123 University of Canberra
16	University of Canberra	1.00000	1.000	Constant	1.000	University of Canberra								
17	University of South Australia	1.00000	1.000	Constant	1.000	University of South Australia								

Notes: to implement improvement for Griffith University, references are made to Deakin (0.011), Monash clayton (0.033), Adelaide (0.478), Queensland (1.733) and Australia (0.205)

Table 5.5A DEA analysis results: 1997

Inputs	**Outputs**
Total Cleaning Costs (AUD)	Gross Floor Area (m2)
Annual cost of Energy purchased (AUD)	Useable Floor Area (m2)
Total security cost (AUD)	EFTSU
Total cost of parking systems (AUD)	Area Maintained from Central Funds (m2)
Preventive & Corrective Maintenance Exper	Area Cleaned from Central Funds (m2)
Total Grounds Maintenance Expenditure (Al	Asset Replacment Value ($)
Cost of purchasing water	Total GFA serviced with Energy (m2)
Total Refurbishment cost($)	Total GFA under security control (m2)
	Number of parking place available
	Ground Area Maintained from Central Funds (m2)

DMU No.	DMU Name	Input-Oriented CRS Efficiency	Σλ	RTS	Benchmarks					
1	Ballarat	1.00000	1.000	Constant	1.000 Ballarat					
2	Curtin	1.00000	1.000	Constant	1.000 Curtin					
3	Deakin University	1.00000	1.000	Constant	1.000 Deakin University					
4	Edith Cowan University	0.84315	2.399	Decreasing	1.243 Monash 3	0.471 Newcastle	0.519 The Uni of Adelaide (Waite)	0.159 The University of	0.007 University of South Australia	
5	James Cook University of North Q	1.00000	1.000	Constant	1.000 James Cook University of North Qld					
6	Macquarie University	1.00000	1.000	Constant	1.000 Macquarie University					
7	Melbourne	1.00000	1.000	Constant	1.000 Melbourne					
8	MONASH 5	1.00000	1.000	Constant	1.000 MONASH 5					
9	Monash 3	1.00000	1.000	Constant	1.000 Monash 3					
10	Murdoch University	1.00000	1.000	Constant	1.000 Murdoch University					
11	Newcastle	1.00000	1.000	Constant	1.000 Newcastle					
12	The Flinders University of SA	1.00000	1.000	Constant	1.000 The Flinders University of SA					
13	The Uni of Adelaide (Waite)	1.00000	1.000	Constant	1.000 The Uni of Adelaide (Waite)					
14	The University of New South Wale	1.00000	1.000	Constant	1.000 The University of New South Wales					
15	The University of Queensland	0.82248	4.159	Decreasing	0.059 Melbourne	2.008 MONASH 5	0.677 Monash 3	1.205 Newcastle	0.025 The University of Syd	0.185 University of South Australia
16	The University of Southern Queen	1.00000	1.000	Constant	1.000 The University of Southern Queensland					
17	The University of Sydney	1.00000	1.000	Constant	1.000 The University of Sydney					
18	The University of Western Austra	0.86331	1.570	Decreasing	0.727 Ballarat	0.154 Deakin Universit	0.199 Melbourne	0.424 Newcastle	0.066 The University of Sydney	
19	University of Canberra	1.00000	1.000	Constant	1.000 University of Canberra					
20	University of South Australia	1.00000	1.000	Constant	1.000 University of South Australia					

Notes: to implement improvement for Edith Cowan, references are made to Monash 3 (1.243), New Castle (0.471), Adelaide (0.519), Queensland (0.159) and Australia (0.007)

Table 5.6A DEA analysis results: 1998

Inputs	**Outputs**
Total Cleaning Costs (AUD)	Gross Floor Area (m2)
Annual cost of Energy purchased (AUD)	Useable Floor Area (m2)
Total security cost (AUD)	EFTSU
Total cost of parking systems (AUD)	Area Maintained from Central Funds (m2)
Preventive & Corrective Maintenance Exper	Area Cleaned from Central Funds (m2)
Total Grounds Maintenance Expenditure (Al	Asset Replacment Value ($)
Cost of purchasing water	Total GFA serviced with Energy (m2)
Total Refurbishment cost($)	Total GFA under security control (m2)
	Number of parking place available
	Ground Area Maintained from Central Funds (m2)

DMU No.	DMU Name	Input-Oriented CRS Efficiency	Σλ	RTS	Benchmarks						
1	Adelaide 3	1.00000	1.000	Constant	1.000 Adelaide 3						
2	ANU	1.00000	1.000	Constant	1.000 ANU						
3	Ballarat	1.00000	1.000	Constant	1.000 Ballarat						
4	Central Queensland University	1.00000	1.000	Constant	1.000 Central Queensland University						
5	Curtin	1.00000	1.000	Constant	1.000 Curtin						
6	Deakin	1.00000	1.000	Constant	1.000 Deakin						
7	Edith Cowan University	0.83040	1.127	Decreasing	0.006 Ballarat	0.049 Curtin	0.326 Deakin	0.684 Flinders	0.012 Melbourne	0.036 Monash 3	0.013 USQ
8	Flinders	1.00000	1.000	Constant	1.000 Flinders						
9	Griffith 4	1.00000	1.000	Constant	1.000 Griffith 4						
10	James Cook Uni	1.00000	1.000	Constant	1.000 James Cook Uni						
11	Macquarie	1.00000	1.000	Constant	1.000 Macquarie						
12	Melbourne	1.00000	1.000	Constant	1.000 Melbourne						
13	MONASH 2	1.00000	1.000	Constant	1.000 MONASH 2						
14	Monash 3	1.00000	1.000	Constant	1.000 Monash 3						
15	MONASH 5	1.00000	1.000	Constant	1.000 MONASH 5						
16	Newcastle	1.00000	1.000	Constant	1.000 Newcastle						
17	QUT	1.00000	1.000	Constant	1.000 QUT						
18	Swinburne	1.00000	1.000	Constant	1.000 Swinburne						
19	Sydney Uni	1.00000	1.000	Constant	1.000 Sydney Uni						
20	Tasmania	1.00000	1.000	Constant	1.000 Tasmania						
21	University of Technology Sydney	1.00000	1.000	Constant	1.000 University of Technology Sydney						
22	UNSW	1.00000	1.000	Constant	1.000 UNSW						
23	UQ	0.87500	4.837	Decreasing	0.145 ANU	0.517 Ballarat	0.577 Deakin	0.901 Flinders	0.066 Melbourne	0.124 Monash 3	2.455 MONASH 5	0.053 University of Technology Sydney
24	USQ	1.00000	1.000	Constant	1.000 USQ						
25	UWA	1.00000	1.000	Constant	1.000 UWA						
26	Wollongong	1.00000	1.000	Constant	1.000 Wollongong						

Notes: to implement improvement for Edith Cowan, references are made to Ballarat (0.006), Curtain (0.049), Deakin (0.326), Flinder (0.684), etc.

Table 5.7A DEA analysis results: 1999

Inputs	**Outputs**
Total Cleaning Costs (AUD)	Gross Floor Area (m2)
Annual cost of Energy purchased (AUD)	Useable Floor Area (m2)
Total security cost (AUD)	EFTSU
Total cost of parking systems (AUD)	Area Maintained from Central Funds (m2)
Preventive & Corrective Maintenance Exper	Area Cleaned from Central Funds (m2)
Total Grounds Maintenance Expenditure (Al	Asset Replacment Value ($)
Cost of purchasing water	Total GFA serviced with Energy (m2)
Total Refurbishment cost($)	Total GFA under security control (m2)
	Number of parking place available
	Ground Area Maintained from Central Funds (m2)

DMU No.	DMU Name	Input-Oriented CRS Efficiency	Σλ	RTS	Benchmarks					
1	ANU	1.00000	1.000	Constant	1.000 ANU					
2	Ballarat	1.00000	1.000	Constant	1.000 Ballarat					
3	Central Queensland University	1.00000	1.000	Constant	1.000 Central Queensland University					
4	Charles Sturt University	1.00000	1.000	Constant	1.000 Charles Sturt University					
5	Curtin	0.96808	1.854	Decreasing	0.319 Central Queensland University	0.013 La Trobe Uni	0.402 MONASH 5	0.353 Monash 3	0.214 UNISA	0.552 USQ
6	Deakin	1.00000	1.000	Constant	1.000 Deakin					
7	Edith Cowan University	1.00000	1.000	Constant	1.000 Edith Cowan University					
8	Flinders	1.00000	1.000	Constant	1.000 Flinders					
9	Griffith	1.00000	1.000	Constant	1.000 Griffith					
10	La Trobe Uni	1.00000	1.000	Constant	1.000 La Trobe Uni					
11	Macquarie	1.00000	1.000	Constant	1.000 Macquarie					
12	Melbourne	1.00000	1.000	Constant	1.000 Melbourne					
13	MONASH 4	1.00000	1.000	Constant	1.000 MONASH 4					
14	MONASH 5	1.00000	1.000	Constant	1.000 MONASH 5					
15	Monash 1	0.94180	0.627	Increasing	0.086 Ballarat	0.024 Griffith	0.277 MONASH 4	0.080 Monash 3	0.160 RMIT	
16	MONASH 2	1.00000	1.000	Constant	1.000 MONASH 2					
17	Monash 3	1.00000	1.000	Constant	1.000 Monash 3					
18	Newcastle	1.00000	1.000	Constant	1.000 Newcastle					
19	RMIT	1.00000	1.000	Constant	1.000 RMIT					
20	Sydney Uni	1.00000	1.000	Constant	1.000 Sydney Uni					
21	UNISA	1.00000	1.000	Constant	1.000 UNISA					
22	University of Technology Sydney	1.00000	1.000	Constant	1.000 University of Technology Sydney					
23	UNSW	1.00000	1.000	Constant	1.000 UNSW					
24	UQ	0.87807	3.994	Decreasing	2.989 Ballarat	0.385 Deakin	0.172 Newcastle	0.020 Sydney Uni	0.428 UNISA	
25	USQ	1.00000	1.000	Constant	1.000 USQ					
26	UWA	0.91763	1.360	Decreasing	0.296 ANU	0.330 Charles Sturt Un	0.121 La Trobe Uni	0.164 MONASH 5	0.402 Monash 3	0.047 Sydney Uni
27	VUT	1.00000	1.000	Constant	1.000 VUT					
28	Wollongong	1.00000	1.000	Constant	1.000 Wollongong					

Notes: to implement improvement for Curtin, references are made to Central Queensland (0.319), La Trobe (0.013), etc.

Table 5.8A DEA analysis results: 2000

Inputs	**Outputs**
Preventive & Corrective Maintenance exper	Gross Floor Area (m2)
Total Cleaning Costs (AUD)	Useable Floor Area (m2)
Total Refurbishment costs (AUD)	EFTSU
Total security cost (AUD)	Area Maintained from Central Funds (m2) except ground area
Total cost of parking systems (AUD)	Area Cleaned from Central Funds (m2)
Total Grounds Maintenance Expenditure (Al	Ground Area Maintained from Central Funds (m2)
	Total GFA under security control (m2)
	Number of parking place available

DMU No.	DMU Name	Input-Oriented CRS Efficiency	Σλ	RTS	Benchmarks							
1	Adelaide 3	1.00000	1.000	Constant	1.000 Adelaide 3							
2	ANU	1.00000	1.000	Constant	1.000 ANU							
3	Ballarat	1.00000	1.000	Constant	1.000 Ballarat							
4	Central Queensland University	1.00000	1.000	Constant	1.000 Central Queensland University							
5	Charles Sturt University	1.00000	1.000	Constant	1.000 Charles Sturt University							
6	Curtin	1.00000	1.000	Constant	1.000 Curtin							
7	Deakin	1.00000	1.000	Constant	1.000 Deakin							
8	Edith Cowan University	0.89253	1.403	Decreasing	0.005 Griffith 3	0.010 La Trobe Uni	0.388 Macquarie	0.009 MONASH 6	0.892 Murdoch 2	0.098 USQ		
9	Flinders	1.00000	1.000	Constant	1.000 Flinders							
10	Griffith 2	0.97350	0.268	Increasing	0.029 La Trobe Uni	0.125 Macquarie	0.108 Murdoch 2	0.007 USQ				
11	Griffith 3	1.00000	1.000	Constant	1.000 Griffith 3							
12	Griffith 4	1.00000	1.000	Constant	1.000 Griffith 4							
13	La Trobe Uni	1.00000	1.000	Constant	1.000 La Trobe Uni							
14	Macquarie	1.00000	1.000	Constant	1.000 Macquarie							
15	Melbourne	1.00000	1.000	Constant	1.000 Melbourne							
16	MONASH 2	0.85629	0.634	Increasing	0.068 Ballarat	0.019 Curtin	0.003 Deakin	0.010 La Trobe Uni	0.200 Monash 3	0.004 MONASH 6	0.295 Murdoch 1	0.018 Murdoch 2	0.016 RMIT
17	Monash 3	1.00000	1.000	Constant	1.000 Monash 3							
18	Monash 4	1.00000	1.000	Constant	1.000 Monash 4							
19	MONASH 5	1.00000	1.000	Constant	1.000 MONASH 5							
20	MONASH 6	1.00000	1.000	Constant	1.000 MONASH 6							
21	Murdoch 1	1.00000	1.000	Constant	1.000 Murdoch 1							
22	Murdoch 2	1.00000	1.000	Constant	1.000 Murdoch 2							
23	Newcastle	0.94260	3.272	Decreasing	0.067 ANU	0.083 Ballarat	0.108 Charles Sturt University	0.505 La Trobe Uni	1.311 Monash 3	1.199 MONASH 5		
24	RMIT	1.00000	1.000	Constant	1.000 RMIT							
25	Sydney Uni	1.00000	1.000	Constant	1.000 Sydney Uni							
26	UNISA	1.00000	1.000	Constant	1.000 UNISA							
27	University of Technology Sydney	1.00000	1.000	Constant	1.000 University of Technology Sydney							
28	UNSW	0.90990	#####	Decreasing	0.377 Charles Sturt University	12.811 MONASH 5	0.525 RMIT	0.412 USQ				
29	UQ	0.78058	3.967	Decreasing	0.401 ANU	0.384 Ballarat	0.222 Deakin	0.555 La Trobe Uni	0.205 Monash 3	2.020 MONASH 5	0.180 RMIT	
30	USQ	1.00000	1.000	Constant	1.000 USQ							
31	UWA	0.88399	1.114	Decreasing	0.377 ANU	0.150 Ballarat	0.348 Charles Sturt University	0.137 Deakin	0.011 La Trobe Uni	0.001 MONASH 6	0.089 RMIT	
32	VUT	0.94784	3.258	Decreasing	1.679 Ballarat	0.075 Deakin	1.396 Monash 4	0.108 RMIT				
33	Wollongong	1.00000	1.000	Constant	1.000 Wollongong							

Notes: to implement improvement for Edith Cowan, references are made to Griffith 3 (0.005), La Trobe (0.01), etc.

Table 5.9A DEA analysis results: 2001

Inputs	**Outputs**
Total Cleaning Costs (AUD)	Gross Floor Area (m2)
Annual cost of Energy purchased (AUD)	Useable Floor Area (m2)
Total security cost (AUD)	EFTSU
Total cost of parking systems (AUD)	Area Maintained from Central Funds (m2)
Preventive & Corrective Maintenance Exper	Area Cleaned from Central Funds (m2)
Total Grounds Maintenance Expenditure (Al	Asset Replacment Value ($)
Cost of purchasing water	Total GFA serviced with Energy (m2)
Total Refurbishment cost($)	Total GFA under security control (m2)
	Number of parking place available
	Ground Area Maintained from Central Funds (m2)

DMU No.	DMU Name	Input-Oriented CRS Efficiency	Σλ	RTS	Benchmarks				
1	Adelaide 1	1.00000	1.000	Constant	1.000 Adelaide 1				
2	ANU	1.00000	1.000	Constant	1.000 ANU				
3	Ballarat	1.00000	1.000	Constant	1.000 Ballarat				
4	Central Queensland University	1.00000	1.000	Constant	1.000 Central Queensland University				
5	Charles Sturt University	1.00000	1.000	Constant	1.000 Charles Sturt University				
6	Curtin	1.00000	1.000	Constant	1.000 Curtin				
7	Edith Cowan University	1.00000	1.000	Constant	1.000 Edith Cowan University				
8	Flinders	1.00000	1.000	Constant	1.000 Flinders				
9	Griffith 1	1.00000	1.000	Constant	1.000 Griffith 1				
10	Griffith 2	1.00000	1.000	Constant	1.000 Griffith 2				
11	Griffith 3	1.00000	1.000	Constant	1.000 Griffith 3				
12	Griffith 4	1.00000	1.000	Constant	1.000 Griffith 4				
13	La Trobe Uni	1.00000	1.000	Constant	1.000 La Trobe Uni				
14	Macquarie	1.00000	1.000	Constant	1.000 Macquarie				
15	Melbourne	1.00000	1.000	Constant	1.000 Melbourne				
16	Monash 1	1.00000	1.000	Constant	1.000 Monash 1				
17	MONASH 2	1.00000	1.000	Constant	1.000 MONASH 2				
18	Monash 3	1.00000	1.000	Constant	1.000 Monash 3				
19	MONASH 4	0.95010	0.203	Increasing	0.146 Ballarat	0.042 Griffith 2	0.009 RMIT	0.002 UNE	0.006 Uni of Canberra
20	Murdoch 2	1.00000	1.000	Constant	1.000 Murdoch 2				
21	Newcastle	1.00000	1.000	Constant	1.000 Newcastle				
22	RMIT	1.00000	1.000	Constant	1.000 RMIT				
23	Sydney Uni	1.00000	1.000	Constant	1.000 Sydney Uni				
24	UNE	1.00000	1.000	Constant	1.000 UNE				
25	Uni of Canberra	1.00000	1.000	Constant	1.000 Uni of Canberra				
26	UNISA	1.00000	1.000	Constant	1.000 UNISA				
27	University of Technology Sydney	1.00000	1.000	Constant	1.000 University of Technology Sydney				
28	UNSW	1.00000	1.000	Constant	1.000 UNSW				
29	UQ	0.98287	4.408	Decreasing	2.243 Ballarat	0.588 Newcastle	0.806 Uni of Canberra	0.064 University of Tec	0.707 Wollongong
30	USQ	1.00000	1.000	Constant	1.000 USQ				
31	UWA	1.00000	1.000	Constant	1.000 UWA				
32	Wollongong	1.00000	1.000	Constant	1.000 Wollongong				

Notes: to implement improvement for Monash 4, references are made to Ballarat (0.146), Griffith 2 (0.042), etc.

Table 5.10A DEA analysis results: 2002

Inputs	**Outputs**
Total Cleaning Costs (AUD)	Gross Floor Area (m2)
Annual cost of Energy purchased (AUD)	Useable Floor Area (m2)
Total security cost (AUD)	EFTSU
Total cost of parking systems (AUD)	Area Maintained from Central Funds (m2)
Preventive & Corrective Maintenance Exper	Area Cleaned from Central Funds (m2)
Total Grounds Maintenance Expenditure (Al	Asset Replacment Value ($)
Cost of purchasing water	Total GFA serviced with Energy (m2)
Total Refurbishment cost($)	Total GFA under security control (m2)
	Number of parking place available
	Ground Area Maintained from Central Funds (m2)

DMU No.	DMU Name	Input-Oriented CRS Efficiency	Σλ	RTS	Benchmarks					
1	Adelaide 1	1.00000	1.000	Constant	1.000 Adelaide 1					
2	ANU	1.00000	1.000	Constant	1.000 ANU					
3	Central Queensland University	0.91886	1.073	Decreasing	0.022 Charles Sturt University	0.009 La Trobe Uni	0.555 MONASH 1	0.252 Monash 5	0.191 Swinburne	0.045 UNISA
4	Charles Sturt University	1.00000	1.000	Constant	1.000 Charles Sturt University					
5	Curtin	1.00000	1.000	Constant	1.000 Curtin					
6	Edith Cowan University	1.00000	1.000	Constant	1.000 Edith Cowan University					
7	Flinders	1.00000	1.000	Constant	1.000 Flinders					
8	Griffith 2	1.00000	1.000	Constant	1.000 Griffith 2					
9	Griffith 3	1.00000	1.000	Constant	1.000 Griffith 3					
10	Griffith 4	1.00000	1.000	Constant	1.000 Griffith 4					
11	James Cook Uni	1.00000	1.000	Constant	1.000 James Cook Uni					
12	La Trobe Uni	1.00000	1.000	Constant	1.000 La Trobe Uni					
13	Macquarie	1.00000	1.000	Constant	1.000 Macquarie					
14	MONASH 1	1.00000	1.000	Constant	1.000 MONASH 1					
15	Monash 2	1.00000	1.000	Constant	1.000 Monash 2					
16	Monash 3	1.00000	1.000	Constant	1.000 Monash 3					
17	MONASH 4	1.00000	1.000	Constant	1.000 MONASH 4					
18	Monash 5	1.00000	1.000	Constant	1.000 Monash 5					
19	MONASH 6	1.00000	1.000	Constant	1.000 MONASH 6					
20	Murdoch 2	1.00000	1.000	Constant	1.000 Murdoch 2					
21	Newcastle	1.00000	1.000	Constant	1.000 Newcastle					
22	Swinburne	1.00000	1.000	Constant	1.000 Swinburne					
23	Sydney Uni	1.00000	1.000	Constant	1.000 Sydney Uni					
24	Tasmania	1.00000	1.000	Constant	1.000 Tasmania					
25	UNE	1.00000	1.000	Constant	1.000 UNE					
26	Uni of Canberra	1.00000	1.000	Constant	1.000 Uni of Canberra					
27	UNISA	1.00000	1.000	Constant	1.000 UNISA					
28	University of Technology Sydney	0.96160	1.446	Decreasing	0.064 Charles Sturt University	0.037 Curtin	0.009 Griffith 3	0.141 Monash 5	1.035 Swinburne	0.160 Tasmania
29	UNSW	1.00000	1.000	Constant	1.000 UNSW					
30	UQ	0.92804	2.823	Decreasing	0.224 Monash 5	0.229 Newcastle	1.442 Swinburne	0.897 UNE	0.032 UNSW	
31	USQ	1.00000	1.000	Constant	1.000 USQ					

Notes: to implement improvement for Central Queensland, references are made to Charles Sturt (0.022), La Trobe(0.009), etc.

Table 5.11A DEA analysis results: 2003

Inputs	**Outputs**
Total Cleaning Costs (AUD)	Gross Floor Area (m2)
Annual cost of Energy purchased (AUD)	Useable Floor Area (m2)
Total security cost (AUD)	EFTSU
Total cost of parking systems (AUD)	Area Maintained from Central Funds (m2)
Preventive & Corrective Maintenance Exper	Area Cleaned from Central Funds (m2)
Total Grounds Maintenance Expenditure (Al	Asset Replacment Value ($)
Cost of purchasing water	Total GFA serviced with Energy (m2)
Total Refurbishment cost($)	Total GFA under security control (m2)
	Number of parking place available
	Ground Area Maintained from Central Funds (m2)
	GFA serviced with water

DMU No.	DMU Name	Input-Oriented CRS Efficiency	Σλ	RTS	Benchmarks													
1	Adelaide 1	1.00000	1.000	Constant	1.000	Adelaide 1												
2	ANU	1.00000	1.000	Constant	1.000	ANU												
3	Central Queensland University	1.00000	1.000	Constant	1.000	Central Queensland University												
4	Charles Sturt University	1.00000	1.000	Constant	1.000	Charles Sturt University												
5	Edith Cowan University	1.00000	1.000	Constant	1.000	Edith Cowan University												
6	Flinders	1.00000	1.000	Constant	1.000	Flinders												
7	Griffith 1	1.00000	1.000	Constant	1.000	Griffith 1												
8	Griffith 3	1.00000	1.000	Constant	1.000	Griffith 3												
9	Griffith 4	1.00000	1.000	Constant	1.000	Griffith 4												
10	James Cook Uni	1.00000	1.000	Constant	1.000	James Cook Uni												
11	La Trobe Uni	1.00000	1.000	Constant	1.000	La Trobe Uni												
12	Macquarie	1.00000	1.000	Constant	1.000	Macquarie												
13	MONASH 1	1.00000	1.000	Constant	1.000	MONASH 1												
14	MONASH 4	1.00000	1.000	Constant	1.000	MONASH 4												
15	Monash 5	1.00000	1.000	Constant	1.000	Monash 5												
16	MONASH 6	1.00000	1.000	Constant	1.000	MONASH 6												
17	Murdoch 2	1.00000	1.000	Constant	1.000	Murdoch 2												
18	Newcastle	1.00000	1.000	Constant	1.000	Newcastle												
19	Southern Cross	1.00000	1.000	Constant	1.000	Southern Cross												
20	Swinburne	1.00000	1.000	Constant	1.000	Swinburne												
21	Sydney Uni	1.00000	1.000	Constant	1.000	Sydney Uni												
22	UNE	1.00000	1.000	Constant	1.000	UNE												
23	Uni of Canberra	1.00000	1.000	Constant	1.000	Uni of Canberra												
24	UNISA	1.00000	1.000	Constant	1.000	UNISA												
25	University of Technology Sydney	0.91361	1.432	Decreasing	0.145	Griffith 3	0.672	Swinburne	0.017	Sydney Uni	0.092	UNE	0.348	UNISA	0.025	UNSW	0.133	USQ
26	UNSW	1.00000	1.000	Constant	1.000	UNSW												
27	UQ	0.95670	8.113	Decreasing	5.545	MONASH 4	0.040	Sydney Uni	1.549	UNE	0.979	UNISA						
28	USQ	1.00000	1.000	Constant	1.000	USQ												
29	Wollongong	1.00000	1.000	Constant	1.000	Wollongong												

Notes: to implement improvement for technology Sydney, references are made to Griffith 3 (0.145), Swinburne(0.672), etc.

Table 5.12A Comparison of DEA analysis results and common FM benchmarks

Institution Name	Input-Oriented CRS Efficiency	Operating Costs per m^2 (GFA)	Operating Costs per EFTSU	Operating Costs as % of ARV	Gross Floor Area (m2)	Useable Floor Area (m2)	UFA/ GFA
Adelaide 3	1.000	**$118.68**	**1871**	0.0666	188,760	128,621	0.681
ANU	1.000	**$34.52**	**1665**	0.0150	370,824	262,329	0.707
Ballarat	1.000	**$36.03**	**521**	0.0307	52,800	36,400	0.689
Central Queensland University	1.000	**$49.36**	**1170**	0.0243	68,828	45,147	0.656
Charles Sturt University	1.000	**$31.47**	**410**	0.0168	216,338	138,317	0.639
Curtin	1.000	**$48.27**	**644**	0.0273	247,548	173,844	0.702
Deakin	1.000	**$32.84**	**659**	0.0200	253,900	206,425	0.813
Edith Cowan University	0.893	**$63.45**	**683**	0.0368	159,712	104,198	0.652
Flinders	1.000	**$44.20**	**713**	0.0262	145,923	98,478	0.675
Griffith 2	0.974	**$64.48**	**684**	0.0280	34,759	25,846	0.744
Griffith 3	1.000	**$49.33**	**400**	0.0242	50,142	39,489	0.788
Griffith 4	1.000	**$64.42**	**1034**	0.0320	119,489	90,359	0.756
La Trobe Uni	1.000	**$36.68**	**642**	0.0253	215,094	133,446	0.620
Macquarie	1.000	**$43.79**	**516**	0.0246	184,056	132,723	0.721
Melbourne	1.000	**$67.84**	**911**	0.0213	363,427	252,774	0.696
MONASH 2	0.856	**$75.01**	**1093**	0.0366	33,455	23,686	0.708
Monash 3	1.000	**$42.75**	**571**	0.0231	49,710	36,610	0.736
Monash 4	1.000	**$53.15**	**584**	0.0191	80,697	50,950	0.631
MONASH 5	1.000	**$183.01**	**3771**	0.0940	13,431	10,260	0.764
MONASH 6	1.000	**$61.88**	**894**	0.0199	293,261	205,215	0.700
Murdoch 1	1.000	**$38.86**	**964**	0.0176	9,058	5,629	0.621
Murdoch 2	1.000	**$46.04**	**569**	0.0213	104,111	69,484	0.667
Newcastle	0.943	**$51.10**	**856**	0.0317	242,278	150,228	0.620
RMIT	1.000	**$78.05**	**773**	0.0396	397,118	295,393	0.744
Sydney Uni	1.000	**$86.89**	**1506**	0.0234	535,862	370,253	0.691
UNISA	1.000	**$65.91**	**813**	0.0314	234,822	183,996	0.784
University of Technology Sydney	1.000	**$80.55**	**1087**	0.0368	245,321	144,880	0.591
UNSW	0.910	**$125.85**	**2507**	0.0619	499,224	308,920	0.619
UQ	0.781	**$65.98**	**1279**	0.0389	453,379	317,365	0.700
USQ	1.000	**$75.39**	**718**	0.0505	90,078	75,380	0.837
UWA	0.884	**$45.35**	**1084**	0.0253	296,103	188,058	0.635
VUT	0.948	**$65.53**	**743**	0.0499	239,297	179,473	0.750
Wollongong	1.000	**$74.00**	**1411**	0.0450	201,015	138,906	0.691
aver		$63.66	1023	0.0329			0.6979
max							0.837

Table 5.13A DEA analysis results with soft and hard data: 2000

Inputs	Outputs
Preventive & Corrective Maintenance expenditu	Preventive & Corrective Maintenance Customer Satisfaction Rating
Total Cleaning Costs (AUD)	Refurbishment Customer Satisfaction Rating
Annual cost of Energy purchased (AUD)	EFTSU
Total Refurbishment costs (AUD)	Area Maintained from Central Funds (m2) except ground area
Total security cost (AUD)	Area Cleaned from Central Funds (m2)
Total cost of parking systems (AUD)	Cleaning and waste management Customer Satisfaction Rating
Total Grounds Maintenance Expenditure (AUD)	Ground Area Maintained from Central Funds (m2)
	Ground Maintenance Customer Satisfaction Rating
	Total GFA under security control (m2)
	Customer Satisfaction Rating on security
	Number of parking place available
	Customer Satisfaction Rating on Parking

DMU No.	DMU Name	Input-Oriented CRS Efficiency	Σλ	RTS	Benchmarks			
1	Griffith 2	1.00000	1.000	Constant	1.000 Griffith 2			
2	Griffith 3	1.00000	1.000	Constant	1.000 Griffith 3			
3	Griffith 4	1.00000	1.000	Constant	1.000 Griffith 4			
4	Macquarie	1.00000	1.000	Constant	1.000 Macquarie			
5	Newcastle	1.00000	1.000	Constant	1.000 Newcastle			
6	UNISA	1.00000	1.000	Constant	1.000 UNISA			
7	UQ	0.97506	2.596	Decreasing	0.606 Griffith 4	0.493 Macquarie	1.383 Newcastle	0.114 USQ
8	USQ	1.00000	1.000	Constant	1.000 USQ			
9	UWA	1.00000	1.000	Constant	1.000 UWA			
10	Wollongong	1.00000	1.000	Constant	1.000 Wollongong			

Notes: To implement improvement for UQ, references are made to Griffith 4 (0.606), Macquarie (0.493), Newcastle (1.383) & USQ (0.114)

Table 5.14A DEA analysis results with soft and hard data: 2001

Inputs	Outputs
Total Cleaning Costs (AUD)	Preventive & Corrective Maintenance Customer Satisfaction Rating
Total security cost (AUD)	Refurbishment Customer Satisfaction Rating
Total cost of parking systems (AUD)	EFTSU
Total Maintenance Expenditure (AUD)	Area Maintained from Central Funds (m2)
Total Refurbishment cost($)	Area Cleaned from Central Funds (m2)
	Cleaning and waste management Customer Satisfaction Rating
	Ground Area Maintained from Central Funds (m2)
	Ground Maintenance Customer Satisfaction Rating
	Total GFA under security control (m2)
	Customer Satisfaction Rating on security
	Number of parking place available
	Customer Satisfaction Rating on Parking

DMU No.	DMU Name	Input-Oriented CRS Efficiency	Σλ	RTS		Benchmarks
1	Charles Sturt University	1.00000	1.000	Constant	1.000	Charles Sturt University
2	Edith Cowan University	1.00000	1.000	Constant	1.000	Edith Cowan University
3	Griffith 1	1.00000	1.000	Constant	1.000	Griffith 1
4	Griffith 2	1.00000	1.000	Constant	1.000	Griffith 2
5	Griffith 3	1.00000	1.000	Constant	1.000	Griffith 3
6	Griffith 4	1.00000	1.000	Constant	1.000	Griffith 4
7	RMIT	1.00000	1.000	Constant	1.000	RMIT
8	UNISA	1.00000	1.000	Constant	1.000	UNISA
9	University of Technology Sydney	1.00000	1.000	Constant	1.000	University of Technology Sydney
10	Wollongong	1.00000	1.000	Constant	1.000	Wollongong

Notes: No relative inefficient unit found.

Table 5.15A DEA analysis results with soft and hard data: 2002

Inputs	Outputs
Total Cleaning Costs (AUD)	Preventive & Corrective Maintenance Customer Satisfaction Rating
Annual cost of Energy purchased (AUD)	Refurbishment Customer Satisfaction Rating
Total security cost (AUD)	EFTSU
Total cost of parking systems (AUD)	Area Maintained from Central Funds (m2)
Preventive & Corrective Maintenance Expenditu	Area Cleaned from Central Funds (m2)
Total Grounds Maintenance Expenditure (AUD)	Cleaning and waste management Customer Satisfaction Rating
Cost of purchasing water	Ground Area Maintained from Central Funds (m2)
Total Refurbishment cost($)	Ground Maintenance Customer Satisfaction Rating
	Total GFA under security control (m2)
	Customer Satisfaction Rating on security
	Number of parking place available
	Customer Satisfaction Rating on Parking

DMU No.	DMU Name	Input-Oriented CRS Efficiency	Σλ	RTS	Benchmarks
1	Edith Cowan University	1.00000	1.000	Constant	1.000 Edith Cowan University
2	Griffith 2	1.00000	1.000	Constant	1.000 Griffith 2
3	Griffith 4	1.00000	1.000	Constant	1.000 Griffith 4
4	Swinburne	1.00000	1.000	Constant	1.000 Swinburne
5	University of Technology Sydney	1.00000	1.000	Constant	1.000 University of Technology Sydney
6	UNSW	1.00000	1.000	Constant	1.000 UNSW
7	UQ	1.00000	1.000	Constant	1.000 UQ

Notes: No relative inefficient unit found.

Table 5.16A DEA analysis results with soft and hard data: 2003

Inputs	**Outputs**
Total Cleaning Costs (AUD)	Preventive & Corrective Maintenance Customer Satisfaction Rating
Total security cost (AUD)	Refurbishment Customer Satisfaction Rating
Total cost of parking systems (AUD)	EFTSU
Preventive & Corrective Maintenance Expenditu	Area Maintained from Central Funds (m2)
Total Grounds Maintenance Expenditure (AUD)	Cleaning and waste management Customer Satisfaction Rating
Total Refurbishment cost($)	Ground Maintenance Customer Satisfaction Rating
	Total GFA under security control (m2)
	Number of parking place available
	Security Customer Satisfaction Rating ON Security
	Customer Satisfaction Rating on Parking
	Area Cleaned from Cent Funds

DMU No.	DMU Name	Input-Oriented CRS Efficiency	Σλ	RTS	**Benchmarks**									
1	Edith Cowan University	1.00000	1.000	Constant	1.000	Edith Cowan University								
2	Flinders	1.00000	1.000	Constant	1.000	Flinders								
3	Griffith 2	1.00000	1.000	Constant	1.000	Griffith 2								
4	James Cook Uni	1.00000	1.000	Constant	1.000	James Cook Uni								
5	Sunshine Coast	1.00000	1.000	Constant	1.000	Sunshine Coast								
6	UNE	1.00000	1.000	Constant	1.000	UNE								
7	University of Technology Sydney	1.00000	1.000	Constant	1.000	University of Technology Sydney								
8	UNSW	1.00000	1.000	Constant	1.000	UNSW								
9	UQ	0.93868	2.069	Decreasing	0.729	Edith Cowan University	0.174	James Cook Un	0.656	Sunshine Coast	0.486	UNE	0.024	University of Technology Sydney
10	USQ	0.79240	1.338	Decreasing	0.126	Griffith 2	0.544	UNE	0.668	University of Technology Sydney				

Notes: To implement improvement for UQ, references are made to Edith Cowan (0.729), James Cook (0.714), etc.