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DATA ENVELOPMENT ANALYSIS IN APARTMENT BUILDING PERFORMANCE MEASUREMENT: A CASE STUDY

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ABSTRACT

This paper examines the improvement of operations and decision-making processes by applying Data Envelopment Analysis (DEA) to appraise the operational efficiency of 24 apartment buildings. In this study, efficiency was based on four dimensions: operational finance, management systems, service quality, and personnel quality. Operational efficiency was assessed using eight items from which five output items were secured. It was observed that the total efficiency for the four dimensions used to measure efficiency was consistently in excess of 90%. The Decision Making Unit (DMU) efficiency was marginally affected by personnel quality. The optimal efficiency for each of the four dimensions was recorded in DMU9 (operational finance), DMU23 (management system), DMU22 (service quality), and DMU18 (personnel quality). DMU10 accounted for four of the five highest efficiency ratings in a single year and can be seen as the benchmark for overall operational efficiency. DMU23 accounted for three of the five lowest efficiency ratings in a single year and was thus the least efficient and can be considered the most in need of urgent improvement. To improve inefficiency, this study applied the CCR model for variable differential analysis in order to decrease the ratio of inputs for each case.

Keywords: Apartment building management, operational performance, data envelopment analysis, decision making unit.

1. INTRODUCTION

Apartment building management (ABM) involves the comprehensive maintenance and management of the hardware and services of a building as well as the software needs of the community and the living environment. The management of apartment buildings requires the integration of a range of services and operations within the business community. ABM is indispensable to the service industry due to its effect on employment and output.

Taiwan features a diverse market that offers a wide range of ABM services that are covered by the laws and regulations related to apartment buildings and include the following: promotion and education, differentiation of ownership rights and obligations, formulation and execution of management rules, equity distribution and dispute mediation, organization registration and management, facilities and equipment maintenance, financing and the use of management fees, preparation and convening of various meetings, development and execution of annual plans, etc. The management and implementation of these business items require the commitment of an experienced team.

Both for-profit and nonprofit organizations hope to maximize their output (or services) and minimize their input, and performance is evaluated on the basis of the balance between inputs and outputs. Performance evaluation is a gauge used for measuring the extent to which an organization is meeting its goals and objectives. This recognizes the contribution of employees as well as the provision of methods for evaluating human resource allocation. Performance evaluation also sheds light on the strategic development processes of organizations. Through the evaluation of staff performance, managers are equipped with information that allows them to achieve their requisite management goals and improve any management shortcomings.

In Taiwan, management companies charged with the management of apartments are selected using a tendering process. Extension of the contracts of these companies is often based on inconsistent onsite performance assessments carried out by a management committee along with the management firm executives. This type of assessment carries with it the undue influence of biased opinions of resident committees or management officials, which does not necessarily reflect the real conditions. Due to a lack of objective field analysis, building management firms face several challenges in establishing sound objectives for assessing performance. The establishment of proper mechanisms would allow management firms to set performance criterions for improving overall operating performance by identifying and improving areas of poor performance.

2. PREVIOUS STUDIES

Many methods are utilized to measure performance practices and although a lot of the measurement methods are practical, they are subject to many restrictions. Table 1 compares commonly used performance assessment methods. DEA determines production boundaries as the measurement of efficiency and refers to the production function in the assessment of efficiency. It does this by using mathematical modelling of inputs and outputs.

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Table 2 shows the key developmental context of DEA theory. The CCR and BCC models, respectively proposed by Charnes et al. (1978) and Banker *et al*. (2004), are considered the most representative. DEA is used extensively within the industrial sector such as in sewage treatment plants (Ramón *et al*., 2012), energy plants (Sueyoshi and Goto, 2012), airports (Wanke, 2012), and in the communications industry (Bayraktar *et al*., 2012). Boscá *et al*. (2011) also employed DEA to combine many assessments into a single performance value, which was used to provide an overall assessment of the organization.

One of the greatest benefits of DEA is that it utilizes vertical and horizontal analysis methods in the assessment of projects and organizations. In this method, vertical analysis compares changes in projects or organizational efficiency using annual data over time (*e.g*., Abad *et al*., 2004; Yao, 2004), while horizontal analysis compares changes in project or organizational efficiency using data in the same year (*e.g*., Ho and Zhu, 2004; Lin, 2008). Horizontal analysis was employed in this study to ascertain the performance assessment of the ABM due to the convenient nature of the cases encountered.

Table 1 Comparison of performance assessment methods

Method	Advantages	Disadvantages
Balanced Scorecard	Links purposes, assessment, goals, and actions as the basis for assessment Strikes a balance between internal and external tools Data transparency and public characteristics	Requires considerable investment of organization resources Less stable organizations may not be able to bear the expense Score ratings are not sufficiently objective or fair Output indicators do not include execution content
Ratio-Analysis	Data can be derived directly from various statistical reports and is meaningful, clear and understandable Results can clearly distinguish between quality and efficiency	Unable to efficiently use resources Unable to process multiple input/output organizational models Inputs and outputs need to consider unit homogeneity issues
Multi-criteria Analysis	Can handle inputs and outputs with multiple factors	Determined standards assume multiple attributes or multiple objectives If extreme values exist, the extent of their representativeness is difficult to determine
Regression-Analysis	Explores efficiency through the relationship of primary dependent and independent variables More scientific results as its based on statistical theory	Without a linear relationship between dependent and independent variables, efficiency values are inaccurate Able only to set a dependent variable, and unable to assess multiple output units Results require subjective confirmation, thus unable to obtain accurate efficiency values
Analytic Hierarchy Process	Helps policy makers understand all levels of performance, and identifies factors which affect performance Through the application of a set of scientific programs, multiple targets, and multiple standards, subjective value judgments of groups can be made objective No upper limit of assessment items	Data collection is difficult Can be arranged in order of priority, but is unable to determine poor performers or make suggestions for improvement Fewer assessment units
Production Frontier Approach	User-friendly statistical method results in more objective assessment results Fewer restrictions and conditions	Must first assume production functions status, with only a single output All inputs and outputs must be quantifiable, unable to simultaneously process multiple input/output problems Residuals assumed to be normally distributed
Data Envelopment Analysis	Can simultaneously process multiple input/output efficiency measurements No default function and parameter estimation problems Assumes the defined pattern premise, does not require statistical testing Not affected by subjective awareness Assessment results are a comprehensive index, conducive to efficiency comparison	Model is highly sensitive and is vulnerable to errors stemming from extreme values Measurement results only meaningful given high homogeneity Unable to process negative outputs

Table 2 Sources for primary DEA development

Study	Primary contribution
Farrell (1957)	First proposed to measure technical efficiency and price efficiency in manufacturing. Established a mathematical programming model for calculation
Charnes *et al*. (1978)	Established a generalized mathematical programming model measuring the production efficiency of inputs and outputs given constant returns to scale
Charnes *et al*. (1983)	Proposed a set of mathematical programming models to assess the efficiency of Cobb-Douglas production functions
Charnes and Cooper (1984)	Proposed non-Archimedean for the CCR model's virtual multipliers
Banker *et al*. (1984)	First proposed to divide the CCR model's technical efficiency into BBC models to measure "pure technical efficiency" and "scale efficiency"
Charnes *et al*. (1985a)	First proposed DEA window analysis
Charnes *et al*. (1985b)	First proposed analysis of DEA sensitivity
Banker *et al*. (1986)	First compared DEA model and Translog cost functions
Dyson and Thanassoulis (1988)	Corrected the DEA model to process efficiency assessment problems when virtual multipliers are restricted
Thompson *et al*. (1990)	Discussed the role of multiplier scope in efficiency analysis in the DEA model
Chang and Guh (1991)	Discussed whether or not DEA is a default function type, and whether or not it can return estimates to scale.
Banker and Thrall (1992)	Investigated DEA estimate returns to scale
Andersen and Petersen (1993)	Proposed a method to further determine similarly efficient DMUs

3. RESEARCH METHODOLOGY

3.1 Basic EDA Model

DEA is an approach used to assess the comparative efficiency of homogeneous operating units. It obtains efficiency values via a mathematical planning approach without the use of production behavior to produce assumptions (or with no alphanumeric settings). Utilizing units with neutral specifics (*i.e.*, the input and output units are inconsistent), it is applied to assess several factors such as technical and allocative efficiency, technological change, and overall factor productivity. The use of DEA in the measurement of performance efficiency requires only inputs and outputs. In doing so there is no need to predetermine the mutual weighting. Additionally, it does not require a large data pool. The technical efficiency (TE) of the standard DEA mode requires input and output data. To obtain efficiency gains, data on inputs, outputs, and output prices are required. To obtain profit efficiency there needs to be concurrent data on volume as well as input and output prices. The origin of DEA is linked to the CCR model developed by Charnes *et al*. (1978) and the BCC model of Banker *et al*. (1984) which are considered two of the most influential DEA models.

3.2 Development of the DEA Model

The DEA model can be characterized by "returns to scale (RS)" and "orientation" into six types. In this study of apartment building management, inputs were minimized, which meant less effort, and this added to the contract price. Therefore, this study employed the inputs of the CCR and BCC models.

Step 1: Defining DMU

To compare the DEA series with the corresponding efficiency of each unit, the DMU requires the following characteristics: (1) similar business goals and similar work characteristics, (2) similar business environment and conditions, and (3) similar inputs and outputs in performance evaluations.

Step 2: Selecting inputs and outputs

The selection of inputs and outputs must be designated through expert opinion, related literature or the factor analysis screening of required variables.

Step 3: Data collection and organization

Once the DMU and "input/output items" have been confirmed, data collection can begin. Because DEA is a confirmed model, it doesn't easily allow for measurement errors, and data accuracy is crucial.

Step 4: Data processing analysis

Once the data for the "inputs/outputs" for each DMU have been collected, Pearson correlation is used to test relevance and positivity and to check whether a large number (*e.g.*, 1,000) of data exist, which may result in a round-off error from virtual multipliers.

Step 5: Constructing a solution model

The Pearson correlation coefficient test is used to determine the inputs and outputs for each dimension, establishing four performance dimensional models as well as determining the efficiency values of each DMU.

Step 6: Presenting and interpreting results

The solution is determined by the above-mentioned mathematical programming models that provide the efficiency values for each DMU, improving the extent and reference units as suggestions for improvement.

3.3 Analysis Methods

<u>Pearson correlation</u>

The degree of correlation for inputs and outputs of each dimension was achieved using the Pearson product differential relation analysis. Although correlation between inputs and outputs can be measured by several statistical methods, the most frequently used method is the Pearson correlation coefficient.

<u>Efficiency analysis</u>

Upon calculating inputs and outputs in DEA, the related efficiency values for each DMU were then obtained. The DMU values reflect the level of efficiency, with corresponding efficiency values of DMU = 1 affirming efficiency and a DMU < 1 affirming inefficiency. The values for DMU were then broken down into 4 types, namely Robustly Efficient Units, Marginally Efficient Units, Marginally Inefficient Units and Distinctly Inefficiently Units (Norman and Stocker, 1991).

<u>Sensitivity analysis</u>

Sensitivity analysis refers to "the degree of influence of a change in the no. of DMUs or of inputs and outputs on the DMUs corresponding efficiency value" (Charnes *et al*., 1985b). Selecting different inputs and outputs results in different efficiency frontiers. By adjusting the inputs and outputs, their contribution to the efficiency and advantages of each DMU can be clearly observed.

<u>Scale efficiency (SE) analysis</u>

The BCC asserts a different variable u_k in order to determine the indicators of RS. A constant RS demonstrates that the DMU is being produced under optimal scale conditions while the efficiency values of the CCR and BCC models are similar. Whenever there is an increasing RS, the DMU is again being produced under optimal scale conditions, however the output rate of increase is greater than that of the input.

<u>Points of improvement</u>

Frontier-Analyst software can assist apartment building managers in enhancing their decision-making and further improving the performance of the organization. In this study, the implementation of Frontier-Analyst software was able to assist with suggestions and goal values for each DMU.

4. RESULTS AND DISCUSSION

4.1 DMU Selection

(1) Homogeneity

In this study, an ABM and maintenance company with a 20-year operating history was used as the test case. The company provides a complete range of building management services and has serviced over 500 cases, including general and luxury residential, commercial, and office buildings.

1) Similar internal character - The company's general residential cases involved management and service items, and these items were similar in a variety of ways.
2) Different external atmosphere - The atmosphere of each case involved a different location, area, number of units, and scale. Each case, therefore, entailed dissimilar personnel inputs.

(2) Number of DMUs

A total of 24 apartment building cases were collected in this study. When assessing efficiency, we allowed the use of the number of input and output items to increase fairly to the number of DMUs. The number of DMUs should preferably be double the total amount of inputs and outputs (Golany and Roll, 1989).

4.2 Initial Selection of Inputs and Outputs

The literature on performance assessment of ABM cases is limited and so provides little guidance regarding the selection of inputs and outputs. Rubenstein and Geisler's (1991) interview method was adopted for this study. Interviews were conducted with the senior management personnel of six top apartment management companies in order to determine the initial inputs and outputs. Each manager interviewed had at least 15 years of ABM experience. Figure 1 indicates the inputs and outputs.

In order to use DEA to measure efficiency levels, the selection of inputs and outputs must conform to isotonicity. As inputs are added, outputs must not be decreased. This study used Pearson correlation coefficient analysis to determine if inputs and outputs were significantly correlated. As shown in Fig. 2, inputs and outputs are positively correlated which means that the study was equipped with logical inputs and outputs.

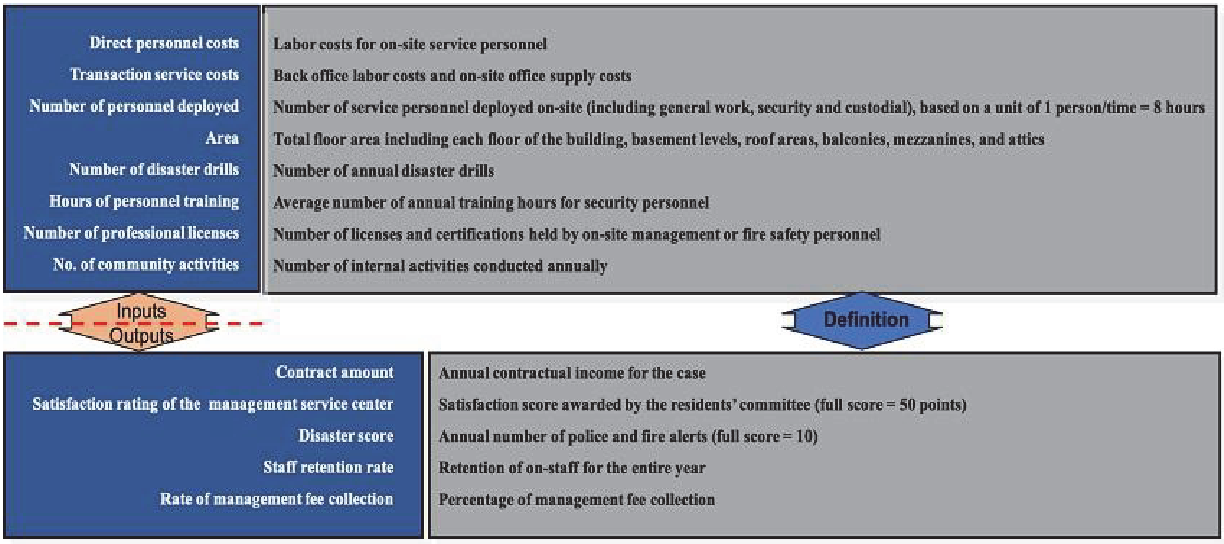

Fig. 1 Inputs and Outputs

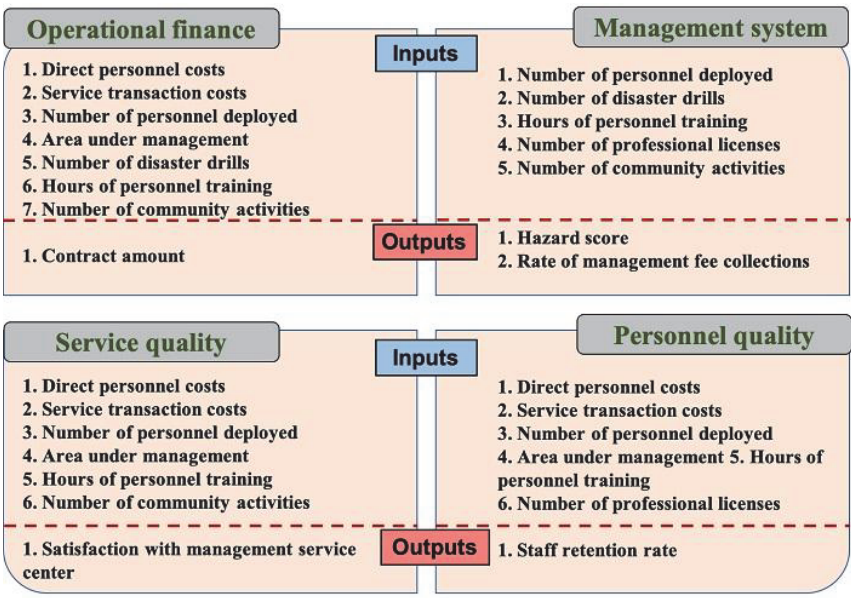

Fig. 2 Summary of Inputs and Outputs for four models

4.3 Overall Efficiency, PTE and SE Analysis

The operational efficiency of this case study was assessed using four dimensions: operational finance (OPF), management systems (MGS), service quality (SVQ), and personnel quality (PSQ). OPF is one example which demonstrates the process of determining the results of the efficiency analysis. The other three dimensions were treated in the same manner.

4.3.1 Overall Efficiency Analysis

The overall efficiency for each of the 24 cases was categorized by the total efficiency (ToE) as well as by the number of references (NF). Values for the DEA ToE were set at 1. Values set at 1 affirm an effective DMU, while those below 1 affirm an ineffective DMU. The overall efficiency for each case was determined by employing the input-oriented CCR methodology. The overall efficiency and reference (ToE and NF) for each sorted case is identified in Table 3. The table displays 15 efficient cases (ToE value = 1), as well as 9 inefficient cases (ToE value < 1). Optimal OPF was found in the top five cases (DMU9, DMU20, DMU16, DMU19, and DMU10). The least optimal cases were (DMU3, DMU23, DMU13, DMU12, and DMU22). DMU9 (referenced nine times) was the most optimal case, followed by DMU20 (referenced five times). On the opposite spectrum, DMU3 was the least optimal case with a ToE of 0.7491 with 25.09% of resources wasted.

4.3.2 Marginal Variable Analysis

Using DEA to assess operational efficiency not only clearly showed corresponding efficient and inefficient DMUs, but through the CCR model it also obtained the ratio of decreased inputs for each case. Because the area under management was not a controllable factor, it was not included in the marginal variable analysis. DEA marginal analysis is oriented towards inputs. In principle, as the number of inputs drops, the number of outputs increases, thus reducing inputs is the goal of the marginal variable value.

Taking Table 3 as an example, the efficiency value is 0.9467. Table 4 shows the integration of the original inputs without uncontrollable items (area under management), which should reduce the ratio of the marginal variables, thus adjusting the input item set. Because some sets did not actually present in fractions of a whole (*e.g.*, numbers of deployed staff or community activities), the numbers were rounded up to maintain more ideal input values (*e.g.*, deployed staff = 6.63 ⊛7, community activities = 4.58 ⊛5). Inefficient cases were also adjusted this way to improve the inefficient case values, as summarized in Table 5 (showing DMUs greater than 0% reduction rate).

4.3.3 PTE, SE and SR Analysis

The CCR model was used to furnish the ToE for each case while the BCC model provided the PTE. The SE was calculated by dividing the ToE by the PTE. The SE confirms whether the inefficiency is caused by the SE or technical inefficiency. If inefficiency is caused by scale inefficiency, then the SR analysis can be used as a gauge to decide whether or not to reduce or expand the scale of operation based on whether the RS is increasing or decreasing. Management control can lead to short term improvement if technical inefficiency is induced by pure technical inefficiency. However, if technical inefficiency is induced by scale inefficiency, then short term improvement will prove difficult. This will then require the integration of SE with RS adjusted to optimal scale. Figure 3 displays the PTE, SE and RS for all cases.

Table 3 DMU ranking by overall efficiency

DMU	ToE	NF	Rank
1	1.0000	2	5
2	0.9467	0	9
3	0.7491	0	15
4	1.0000	2	5
5	1.0000	2	5
6	1.0000	1	6
7	1.0000	1	6
8	1.0000	1	6
9	1.0000	10	1
10	1.0000	3	4
11	1.0000	2	5
12	0.8181	0	12
13	0.8126	0	13
14	1.0000	1	6
15	1.0000	1	6
16	1.0000	4	3
17	1.0000	2	5
18	0.9661	0	8
19	1.0000	4	3
20	1.0000	6	2
21	0.9803	0	8
22	0.8602	0	11
23	0.8015	0	14
24	0.8934	0	10

Table 4 DMU2 near-ideal input items and values

Original input	Input value	Value without uncontrollable items	Reduced ratio of margin variables	Values following adjustment of the input set	Near-ideal input value
Direct personnel costs	214.2	214.2	-5.3%	202.85	202.85
Service transaction costs	105.6	105.6	-18.6%	85.96	85.96
Deployed staff	7	8	-5.3%	6.63	7*
Area under management	9	Uncontrollable item (deleted)			
Hours of personnel training	38	38	-5.3%	35.99	35.99
Community activities	5	5	-8.5%	4.58	5*

Note: Numbers rounded up.

Table 5 Input marginal variables by DMU

DMU	Input (% reduction)				
	Direct personnel costs	Service transaction costs	Deployed staff	Hours of staff training	Community activities
2	5.3	18.6	5.3	5.3	8.5
3	25.1	70.8	25.1	55.1	25.1
12	18.2	31.4	18.2	28.4	18.2
13	18.7	18.7	18.7	64.7	25.8
18	3.4	3.4	20.8	48.8	3.4
21	2	43.3	20.6	54.4	2
22	14	14	16.6	42.4	15.8
23	19.9	19.9	19.9	35.9	45.8
24	10.7	10.7	27.4	10.7	11.6

DMU	ToE	PTE	SE	RS
01	1.0000	1.0000	1.0000	CRS
02	0.9467	1.0000	0.9467	DRS
03	0.7491	0.9274	0.8077	DRS
04	1.0000	1.0000	1.0000	CRS
05	1.0000	1.0000	1.0000	CRS
06	1.0000	1.0000	1.0000	CRS
07	1.0000	1.0000	1.0000	CRS
08	1.0000	1.0000	1.0000	CRS
09	1.0000	1.0000	1.0000	CRS
10	1.0000	1.0000	1.0000	CRS
11	1.0000	1.0000	1.0000	CRS
12	0.8181	0.9092	0.8998	IRS
13	0.8126	1.0000	0.8126	DRS
14	1.0000	1.0000	1.0000	CRS
15	1.0000	1.0000	1.0000	CRS
16	1.0000	1.0000	1.0000	CRS
17	1.0000	1.0000	1.0000	CRS
18	0.9661	1.0000	0.9661	DRS
19	1.0000	1.0000	1.0000	CRS
20	1.0000	1.0000	1.0000	CRS
21	0.9803	1.0000	0.9803	DRS
22	0.8602	1.0000	0.8602	DRS
23	0.8015	0.9080	0.8827	IRS
24	0.8934	0.9138	0.9777	IRS

Fig. 3 Summary of PTE, SE and RS for 24 DMUs

According to Norman and Stocker (1991), DMUs are classified according to the following four standards:

(1) Robustly Efficient Units

In this case, the ToE, PTE and the SE are at 1. Unless there are changes in materials in the future, when looking at multiple DMUs, the RS should be fixed or the efficient state should be maintained. It is therefore unnecessary to increase outputs or reduce inputs to continue the prevailing production scale. Examples of DMUs with robustly efficient units are DMU9 (referenced 10 times), DMU20 (referenced 6 times), DMU16 (referenced 4 times), DMU19 (referenced 4 times), and DMU10 (referenced 3 times).

(2) Marginal Efficient Units

In this case the ToE, PTE and SE are at 1, similar to the first standard, although the number of references are limited to one or two appearances. In this scenario, any small change in inputs and outputs would cause the efficiency value to dip below 1. Examples of DMUs with marginal efficient units are DMU4, DMU5, DMU11, and DMU17, each of which were referenced two times and DMU6, DMU7, DMU8, DMU14, and DMU15, all of which were referenced once.

(3) Marginal Inefficient Units

In this case the value of the ToE is below 1 but greater than 0.9. If the ToE and SE values are both less than 1 but greater than 0.9 and the PTE equals 1, then the efficiency will be caused by scale inefficiency. Examples of this can be seen in DMU2, DMU18, and DMU21 and are categorized as decreasing RS. To improve efficiency would require an improvement of the scale of production. In cases where the SE is greater than the ToE and near to 1, the efficiency/inefficiency would be caused by technical inefficiency. Maximum outputs while using the most appropriate inputs would improve inefficiency. A case of this type was not realized in the performance dimensions of this study.

(4) Distinctly Inefficient Units

In this case the value of the ToE is well below 0.9. Examples of this can be seen in DMU3 (0.7491), DMU12 (0.8181), DMU13 (0.8126), DMU22 (0.8602), DMU23 (0.8015), and DMU24 (0.8934). In many cases the ToE, PTE and SE may be below 1, e.g., DMU3, DMU12, DMU23, and DMU24. Both technical inefficiency and scale inefficiency could be the cause of overall inefficiency. Concurrent efforts towards improvement of both the ratio of inputs and outputs would require adjustment to the scale of production.

4.3.4 Sensitivity Analysis

The DEA efficiency value is frequently affected by the selected input and output items. Each decrease in inputs requires a recalculation of the DEA to check whether the changes have affected the efficiency values. This study used successive deletion of each input to determine sensitivity (see Table 9). For example, deleting the "Direct Personnel Costs" input resulted in 9 corresponding efficiency units (as opposed to six originally), $EAI = \left| \frac{15-9}{15} \times 100\% \right| = 40\%$. Deleting the "Professional Licenses Obtained" input resulted in 15 corresponding efficiency units which indicated that the "Professional Licenses Obtained" input would not affect the number of corresponding efficiency units. Table 6 shows that direct personnel costs, service transaction costs, deployed staff and area under management were important performance assessment items and that these four dimensions had a definite effect on the DEA model's corresponding efficiency value assessment, while the effect of staff training hours was smaller.

Table 6 Sensitivity of selected deleted inputs

Overall efficiency value	Cases in which overall efficiency = 1 (a)	Cases in which overall efficiency < 1 (b)	EAI
Original data	15	0	—
Delete direct personnel costs	9	6	40%
Delete service transaction costs	9	6	40%
Delete deployed staff	11	4	26.7%
Delete area under management	10	5	33.3%
Delete number of staff training hours	14	1	6.7%
Delete professional licenses obtained	15	0	0%

4.4 Integrated Analysis of Dimension Performance

Table 7 displays DMUs which occurred at least twice among the top five cases and the bottom five cases for each of the four dimensions of performance. The DMUs in the top five were DMU10 (4 occurrences); DMU6, DMU5, and DMU18 (3 occurrences each); and DMU1, DMU4, DMU11, DMU13, DMU17, DMU22, and DMU24 (2 occurrences each). DMUs in the bottom five were DMU22 (3 occurrences); DMU3, DMU9, DMU14, DMU20, and DMU22 (2 occurrences each). The important effect of each dimension performance is clearly displayed in Table 8. Table 9 displays the average efficiency values and resources wasted for each of the four dimensions:

1. The four dimensions had an overall efficiency in excess of 0.9. However, the PSQ had the lowest efficiency values which indicated that the efficiency frontier was reached due to the limit of the DMU's PSQ performance.
2. Within the OPF dimension, the ToE was 0.9512, reflecting that 4.88% of case resources were wasted. The average efficiency of the PTE and SE were 0.9858 and 0.9639, respectively, corresponding to resource wastage of 1.42% and 3.61%, respectively.
3. Within the MGS dimension, the ToE was 0.9605, reflecting that 3.95% of case resources were wasted. The average efficiency of the PTE and SE were 0.9739 and 0.9856, respectively, corresponding to resource wastage of 2.61% and 1.44%, respectively.
4. Within the SVQ dimension, the ToE was 0.9144, reflecting that 8.56% of case resources were wasted. The average efficiency of the PTE and SE were 0.9417 and 0.9708, respectively, corresponding to resource wastage of 5.83% and 2.92%, respectively.
5. Within the PSQ dimension, the ToE was 0.8436, reflecting that 15.64% of case resources were wasted. The average efficiency of the PTE and SE were 0.9739 and 0.8655, respectively, corresponding to resource wastage of 2.61% and 13.45%, respectively.

Table 7 Top five OPE performers for each dimension

5th	DMU1, DMU4, DMU11, DMU12, DMU17	DMU1, DMU11, DMU12, DMU13	DMU22	DMU18
4th	DMU10	DMU2, DMU4, DMU6, DMU17, DMU18, DMU21	DMU5	DMU13
3rd	DMU16, DMU19	DMU19	DMU6	DMU10
2nd	DMU20	DMU5, DMU10, DMU22	DMU10	DMU6, DMU19
1st	DMU9	DMU24	DMU18	DMU8, DMU24
Rank of Dimension	Better ← OPE → Worse			
	OPF	MGS	SVQ	PSQ
	Worse ← OPE → Better			
Last	DMU3	DMU14	DMU20	DMU22
2nd to last	DMU23	DMU9	DMU11	DMU3
3rd to last	DMU13	DMU20	DMU9	DMU4
4th to last	DMU12	DMU23	DMU14	DMU2
5th to last	DMU22	DMU16	DMU23	DMU7

Table 8 Effects of dimensions on performance inputs

Affected item / Dimension	Heavily affected inputs	Lightly affected inputs
OPF	Direct personnel costs, service transaction costs, deployed personnel, area under management	Hours of staff training, professional licenses obtained
MGS	Deployed personnel, number of disaster drills, hours of staff training, professional licenses obtained, community activities	
SVQ		Direct personnel costs, service transaction costs, deployed personnel, area under management, hours of staff training, professional licenses obtained
PSQ	Service transaction costs	Direct personnel costs, deployed staff, area under management, hours of staff training, professional licenses obtained

Table 9 Dimension-based average ToE and resources wasted

Indicator Dimension	ToE		PTE		SE	
	Average ToE	Resource wastage	Average efficiency	Resource wastage	Average efficiency	Resource wastage
OPF	0.9512	4.88%	0.9858	1.42%	0.9639	3.61%
MGS	0.9605	3.95%	0.9739	2.61%	0.9856	1.44%
SVQ	0.9144	8.56%	0.9417	5.83%	0.9708	2.92%
PSQ	0.8436	15.64%	0.9739	2.61%	0.8655	13.45%

5. CONCLUSIONS AND RECOMMENDATIONS

This study utilized a DEA equipped with four dimensions, eight inputs, and five outputs to measure the annual operational performance of 24 apartment buildings. The operational performance and suggested values corresponding to each case can provide suggestions for deliberation and improvement of high-level decision making. The key findings include:

1. An important function within DEA assessment of operational efficiency is determining the right inputs and outputs. Considering that the measurement of ABM performance involves numerous inputs and outputs, other research with contrasting objectives may produce variation in selecting inputs and outputs. Careful consideration is necessary when making this decision.
2. This study employed the Pearson correlation coefficient to establish inputs and outputs. The input variables consisted of the following 8 areas: direct personnel cost, cost of service transaction, number of service personnel used on site, areas under management, number of disaster drills, hours of staff training, tally of professional licenses, and number of activities conducted within the community. The outputs consisted of the following: contract amount, satisfaction score of management services, disaster score, staff retention rate, and the percentage of management fee collection. This study satisfied the isotropic assumption of the DEA model. This assumption implies that an increase in inputs will not reduce outputs.
3. The ToE average of the four dimensions used to evaluate DMU efficiency were typically greater than 0.9. Of these dimensions, PSQ attained the lowest efficiency score, demonstrating that the quality of the personnel contributed minimally to DMU efficiency. This study showed that the optimal efficiency in each dimension were DMU9 (OPF), DMU24 (MGS), DMU22 (SVQ), and DMU18 (PSQ), respectively.
4. The proposed adjustment method allowed for the improvement of inefficient situations. Taking E3 as an example, the main cause of inefficiency was scale inefficiency. Therefore, at this stage of field operations review, increasing or decreasing RS and implementing the required expansion or reduction of SE could improve overall operational efficiency. From the operational dimension, the efficiency value of DMU2 was 0.9467, and the original input set was (direct personnel costs = 214.2, service transaction costs = 105.6, deployed personnel = 7, area under management = 9; hours of staff training = 38, community activities = 5). Removing uncontrollable items (area under management), the input set was adjusted as follows: direct personnel costs (202.85), service transaction costs (85.96), deployed personnel (7), hours of staff training (35.99), and community activities (5). This adjustment method allows for the improvement of inefficient situations.
5. Sensitivity analysis showed the key influence of each dimension. Taking OPF as an example, direct personnel costs, service transaction costs, deployed staff, and area under management were all important performance assessment items and had a definite effect on the efficiency value corresponding to the DEA model assessment. The MGS dimension had a significant degree of influence but SVQ was not the same. PSQ was equipped with a significant degree of influence on service transaction costs, with less influence elsewhere.
6. The average efficiency values of the OPF showed that the PTE was 0.9858 and the SE was 0.9639. Additionally, the resource wastage for the PTE and SE were 1.42% and 3.61%, respectively. The resource wastage for the MGS showed that the PTE and SE were 2.61% and 1.44%, respectively. Resource wastage for the SVQ dimension were 5.83% and 2.92% for the PTE and SE, respectively. Within the PSQ dimension, resource wastage accounted for 2.61% and 13.45% for PTE and SE, respectively.
7. DMU10 can be seen as the benchmark case for this study. DMU10 was present across all four dimensions within the top five operational efficiency performers. On the opposite side of the spectrum, DMU23 was present across three dimensions (OPF, MGS, SVQ) and rated as the least operationally efficient decision making unit. This unit exemplified the worst-case scenario and would require the greatest amount of future development.

This study used DEA to assess the relative efficiency of each case, rather than absolute efficiency, and the results were influenced by the selection of the DMU. The addition of other cases or changes to the existing cases could produce different results. If the newly added cases performed progressively better, the efficiency value corresponding to each case could fall. If the newly added cases performed progressively worse, the efficiency value corresponding to each case could rise. In addition, this study was limited by the difficulty of obtaining data and was based on only one year's data. If future studies are able to obtain case data for different years, a longitudinal study may provide an effective comparison.

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