Apartment Building Management Performance Assessment Using Data Envelopment Analysis

Wei Tong Chen and Jien-Bin Jian
Department of Construction Engineering
National Yunlin University of Science and Technology
Touliu, Yunlin 640, Taiwan
chenwt@yuntech.edu.tw, jimmy74712@gmail.com

Hong Long Chen
Department of Business and Management
National University of Tainan
Tainan, 700, Taiwan
along314@mail.nutn.edu.tw

Abstract

This study reviews improvement of operations and decision making through the utilization of data envelopment analysis (DEA) to assess the operational efficiency of 24 apartment buildings based on four dimensions: operations finance, management systems, service quality and personnel quality. Eight items are used to assess case operational efficiency and five output items are obtained. It is found that the total efficiency typically averaged more than 90% for the four dimensions used to evaluate case efficiency. Personnel quality made little contribution to Decision Making Unit (DMU) efficiency. The optimal efficiency for each dimension was found in DMU09 (operational finance), DMU23 (management system), DMU22 (service quality) and DMU18 (personnel quality). DMU10 is considered the benchmark case while DMU23 is the least ideal and most in need of improvement.

Keywords
Apartment building, performance assessment, data envelopment analysis

1. Introduction
Apartment building management requires integrating a variety of business operations and services, and is a fundamental key service industry with considerable output value and employment effects. The management and execution of these business items requires the attention of a professional team. In Taiwan, apartment building management firms (ABMFs) are typically selected by tender, and determination of whether to extend the contract for the following year is made through irregular on-site performance assessments by the management committee accompanied by management firm executives. This type of assessment method is easily influenced by the subjective opinions of the resident management committee members or the management firm executives, and does not easily reflect actual objective conditions. Therefore, Taiwan’s ABMFs face a serious challenge in establishing an objective and reasonable comparison mechanism based on objective field data analysis as the basis for performance assessment. Such a mechanism would establish performance benchmarks, identify areas of poor performance and assist the organization in improving overall operating performance.

Performance assessment not only allows for an understanding of employee contributions, but also provides insight into the degree to which an organization has realized its goals, thus providing solutions for assessing the effectiveness of human resource allocation and the organization’s strategic development process. Assessing staff performance provides managers with information required to achieve the organization’s goals and improve management deficiencies.

Through mathematical modeling of inputs and outputs, data envelopment analysis (DEA) calculates production boundaries as the basic measurement of efficiency, citing the concept of the production function in executing efficiency assessment. DEA is widely used in various industrial sectors including sewage treatment plants (Ramón et al. 2012), airport (Wanke 2012), communications (Bayraktar et al. 2012), and energy (Sueyoshi and Goto 2012). It is also utilized to simplify numerous assessment data into single performance values (Boscá et al. 2011), and achieve the overall assessment of an organization. The CCR and BCC models, respectively proposed by Charnes, A., Cooper, W.W., and Rhodes, E. (Charnes et al. 1978) and Banker, R.D., Charnes, A., and Cooper, W.W. (Banker et al. 1984), are considered the most representative. DEA is mostly used to assess organizations and projects, with analysis methods divided into vertical and horizontal for comparison. The main difference is that vertical analysis uses different annual data to discover changes in efficiency between organizations or projects (e.g., Abad et al. 2004; Seiford and Zhu 1999), while horizontal analysis compares performance between organizations and projects in the same year (e.g., Ho and Zhu 2004). This paper focuses on performance assessment in apartment building management, particularly in terms of the ad hoc nature of cases, and thus employs horizontal analysis.

2. Research Methodology

2.1. Development of the DEA Model

DEA is a method of measuring the comparative efficiency of homogeneous operating units. It obtains efficiency values through mathematical planning methods without the need of production behavior to produce assumptions. Using unit with neutral characteristics, it is applied to measure technical efficiency, allocation efficiency, technological change and changes in total factor productivity. When using DEA for evaluation, only inputs and outputs need to be determined, and it is not necessary to pre-determine mutual weighting, nor is a large data sample required. The data required for DEA can be determined according to the desired efficiency type. To obtain technical efficiency, standard mode DEA requires input and output data. Obtaining efficiency gains requires data on inputs, outputs and output prices. Obtaining profit efficiency requires simultaneous data on input and output prices and volume. DEA originated in the CCR model proposed by Charnes et al. (1978), followed by the BCC model proposed by Banker et al. (1984). These two models are considered to be the most influential in DEA. The DEA model can be differentiated by "return to scale" and "orientation" into six types. For the purposes of apartment building case management, reducing inputs is far easier adding to the contract price. Thus this study uses the input orientation of the CCR and BCC models.

2.2. Types of analysis performed

This research uses the Person correlation coefficient test to select the inputs and outputs for each dimension, constructing four performance dimensional models and separately solving the efficiency value of each DMU. Person product differential relation analysis is performed to determine the degree of correlation for the inputs and outputs of each dimension, and the correlation between the two variables can be measured by multiple statistical methods. One of the most commonly used methods is linear correlation coefficient (*r*, Pearson correlation coefficient).

Once inputs and outputs have been calculated in DEA, the corresponding efficiency values for each DMU can be obtained. When the efficiency value of DMU=1, it represents that the DMU is correspondingly efficient. When the corresponding efficiency value < 1, it represents that the DMU is correspondingly inefficient. DMU can be differentiated into four types based on overall efficiency values: Robustly Efficient Units, Marginal Efficient Units, Marginal Inefficient Units, and Distinctly Inefficient Units (Norman and Stocker 1991; Seiford and Zhu 1999).

The BCC model imports a new variable u_k to determine the indicators of returns to scale. Constant returns to scale indicate the DMU is producing under optimal scale conditions, where the BCC and CCR models have similar efficiency values. Decreasing scale returns indicate the DMU is producing under greater than optimal scale conditions, and the rate of increase for outputs is less than that for inputs. Increasing scale returns indicate that the DMU is producing at lowers than optimal conditions, and that the rate of increase for outputs is greater than that of inputs. Implementing Frontier-Analyst software can raise suggestions and goal values for each DMU, as reference for apartment building managers decision-making and improvement efforts.

3. Results and Discussion

This study collected 24 residential building apartment cases which met the assessment criteria, and assessed the efficiency value corresponding to each case according to input and output data. This study followed Rubenstein and Geisler's (1991) expert interview method, and the researchers interviewed the top management of six top apartment management companies to select the initial inputs and outputs. Each interviewee had at least 15 years of property management experience. This research implements Pearson correlation coefficient analysis to determine whether inputs and outputs are significantly correlated. Table 1 shows that inputs and outputs are positively correlated, indicating that the inputs and outputs selected for this study are reasonable. This study assesses case operational efficiency through four dimensions: operational finance, management system, service quality and personnel quality. Below, operational finance is taken as an example to illustrate overall the process and results of efficiency analysis, with the analysis of the other dimensions following a similar process.

Table 1: Inputs and outputs for different models

Item	Operational finance	Management system	Service quality	Personnel quality
Inputs				
Direct personnel costs	I		I	I
Service transaction costs	I		I	I
Number of personnel deployed	I	I	I	I
Area under management	I		I	I
Number of disaster drills	I	I		
Hours of personnel training	I	I	I	I
Number of professional licenses		I		I
Number of community activities	I	I	I	
Outputs				
Contract amount	O			
Satisfaction with management service center			O	
Hazard score		O		
Staff retention rate				O
Rate of management fee collections		O		

Note: I is the selected inputs; O is the selected outputs.

3.1 Overall Efficiency Analysis

The CCR model allows the DMU being measured to determine the set of optimal weights for each of DMU's factors so as to maximize its efficiency. The solution consists of a set of weights chosen so that the efficiency of any other unit with these weights won't exceed 1, the value at which a unit is relatively efficient. The overall efficiency of each DMU is sorted by total efficiency and number of references. DEA total efficiency value is set at 1 to correspond to effective DMUs, while those below 1 correspond to ineffective DMUs.

This study uses the CCR input-oriented to obtain the overall efficiency of each DMU, separately sorting DMUs by overall efficiency (total efficiency and number of references), as seen in Table 2. The table shows 15 efficient cases (total efficiency value = 1), and nine inefficient cases. Operational efficiency is optimal in the top five cases (DMU09, DMU20, DMU16, DMU19 and DMU10) and least optimal in the bottom five cases (DMU03, DMU23, DMU13, DMU12 and DMU22). DMU09 is the most optimal case, and was referred to nine times by inefficient cases, followed by DMU20 (referred to 5 times). DMU03 was the least optimal case, with a total efficiency of 0.7491, with 25.09% of resources being wasted.

3.2 Pure Technical Efficiency, Scale Efficiency and Scale of Return Analysis

Using the CCR model can obtain the total efficiency for each case. The pure technical efficiency can then be obtained through the BCC model, and dividing the total efficiency by pure technical efficiency obtains scale efficiency, thus confirming whether the inefficiency is due to scale inefficiency or technical inefficiency. If it's due to scale inefficiency, scale of return analysis can determine whether to expand or reduce the scale of operations, depending on whether the return of scale is increasing or decreasing. If technical inefficiency is prompted by pure technical inefficiency, it is subject to management control and could be improved in the short term. If it comes from scale inefficiency, it would be difficult to improve in the short term, and may require the integration of scale efficiency and return of scale to be adjusted to optimal scale. Table 3 presents the pure technical efficiency, scale efficiency and return of scale for all cases.

Table 2: Ranking of DMUs by overall efficiency

DMU	Total efficiency	Number of references	Rank
01	1.0000	2	5
02	0.9467	0	9
03	0.7491	0	15
04	1.0000	2	5
05	1.0000	2	5
06	1.0000	1	6
07	1.0000	1	6
08	1.0000	1	6
09	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 3: Pure technical efficiency, scale efficiency and return of scale for all cases

DMU.	Total efficiency	Pure technical efficiency	Scale efficiency	Return of scale
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

Note: Total efficiency = Pure technical efficiency* Scale efficiency

Norman and Stocker (1991) differentiated DMU based on the following four standards:

● The Robustly Efficient Units

Total efficiency, pure technical efficiency and scale efficiency are all 1. Barring future material changes, in considering multiple DMUs, returns to scale should be fixed or it may maintain an efficient state. Thus, there is no need to add outputs or decrease inputs to maintain the current production scale. For example: DMU09 (10 times), DMU20 (6), DMU16 (4), DMU19 (4) and DMU10 (3).

● The Marginal Efficient Units

Total efficiency, pure technical efficiency and scale efficiency are all 1, and efficiency reference sets appear only once or twice. If there is a slight change in inputs or outputs, the efficiency value may be below 1. For example: DMU04 (2 times), DMU05 (2), DMU11 (2), DMU17 (2), DMU06 (1), DMU07 (1), DMU08 (1), DMU14 (1), and DMU15 (1).

● The Marginal Inefficient Units

Unit total efficiency value is below 1 but greater than 0.9. If the total efficiency value is not equal to 1, but because pure technical efficiency is 1 and scale efficiency is less than 1, therefore the total efficiency and inefficiency stems from scale inefficiency. For example: DMU02, DMU18 and DMU21 are stages of decreasing scale of returns, and the scale of production should be improved to improve inefficiencies. If scale efficiency values are very close to 1 and the scale inefficiency value is greater than the pure technical efficiency value, then total efficiency/inefficiency stems from technical inefficiency. To improve these inefficiencies, the most appropriate inputs should be used to maximize outputs. Fortunately, this type of situation did not arise in the performance dimensions.

● The Distinctly Inefficient Units

Unit efficiency values are significantly below 0.9, e.g., DMU03(0.7491), DMU12(0.8181), DMU13(0.8126), DMU22(0.8602), DMU23(0.8015) and DMU24(0.8934). Total efficiency, pure technical efficiency and scale efficiency may all be below 1, with inefficiency stemming from technical inefficiency or scale inefficiency. Therefore, improving this type of inefficient situation requires simultaneous improvement of the ratio of inputs and outputs to adjust the scale of production.

3.3 Integrated Analysis for Each Performance Dimension

Table 4 shows MDUs which appear at least twice among the top five for each dimension of operational efficiency. In order they are DMU10 (4 times); DMU06, DMU05 and DMU18 (three times each); and DMU01, DMU04, DMU11, DMU13, DMU17, DMU22 and DMU24 (two times each). Cases which appear at least twice among the bottom five for each dimension of operational efficiency include DMU22 (three times); DMU03, DMU09, DMU14, DMU20 and DMU22 (two times). Table 5 shows the operational efficiency assessment results for each case by dimension:

1. The overall efficiency of the four dimensions is generally higher than 0.9. Personnel quality was the lowest, indicating that the DMU's limited personnel quality performance reaches the efficiency frontier.
2. The total efficiency of the operational finance dimension was 0.9512, indicating that 4.88% of case resources were wasted in this dimension. Pure technical efficiency and scale efficiency were 0.9858 and 0.9639, respectively, indicating that 1.42% of the resource wastage was due to technical inefficiency, while 3.61% was due to scale inefficiency.
3. The total efficiency of the management system dimension was 0.9605, indicating that 3.95% of case resources were wasted in this dimension. Pure technical efficiency and scale efficiency were 0.9739 and 0.9856, respectively, indicating that 2.61% of the resource wastage was due to technical inefficiency, while 1.44% was due to scale inefficiency.
4. The total efficiency of the service quality dimension was 0.9144, indicating that 8.56% of case resources were wasted in this dimension. Pure technical efficiency and scale efficiency were 0.9417 and 0.9708, respectively, indicating that 5.83% of the resource wastage was due to technical inefficiency, while 2.92% was due to scale inefficiency.
5. The total efficiency of the personnel quality dimension was 0.8436, indicating that 15.64% of case resources were wasted in this dimension. Pure technical efficiency and scale efficiency were 0.9739 and 0.8655, respectively, indicating that 2.61% of the resource wastage was due to technical inefficiency, while 13.45% was due to scale inefficiency.

Table 4: Top five operational efficiency performers for each dimension

Rank / Performance dimension	Better ←Operational efficiency → Worse					Worse ←Operational efficiency →Better				
	1st	2nd	3rd	4th	5th	Last	2nd to last	3rd to last	4th to last	5th to last
Operational finance	MDU09	DMU20	DMU16 DMU19	DMU10	DMU01 DMU04 DMU12 DMU11 DMU17	DMU03	DMU23	DMU13	DMU12	DMU22
Management system	DMU24	DMU05 DMU10 DMU22	DMU19	DMU02 DMU04 DMU06 DMU17 DMU18 DMU21	DMU01 DMU11 DMU12 DMU13	DMU14	DMU09	DMU20	DMU23	DMU16
Service quality	DMU22	DMU05	DMU06	DMU10	DMU18	DMU20	DMU11	DMU09	DMU14	DMU23
Personnel quality	DMU18	DMU13	DMU10	DMU06 DMU19	DMU08 DMU24	DMU22	DMU03	DMU04	DMU02	DMU07

Table 5: Average efficiency value and resource wasted for each DMU by dimension

Performance indicator / Performance dimension	Total efficiency		Pure technical efficiency		Scale efficiency	
	Average total efficiency	Resource wastage	Average efficiency value	Resource wastage	Average efficiency value	Resource wastage
Operational finance	0.9512	4.88%	0.9858	1.42%	0.9639	3.61%
Management system	0.9605	3.95%	0.9739	2.61%	0.9856	1.44%
Service quality	0.9144	8.56%	0.9417	5.83%	0.9708	2.92%
Personnel quality	0.8436	15.64%	0.9739	2.61%	0.8655	13.45%

4. Conclusions

This study uses the DEA with four dimensions (operational finance, management system, service quality and personnel quality) with eight inputs and five outputs to assess the annual operational performance of 24 cases of an ABMF. Apartment building management involves multiple inputs and outputs, and, in DEA assessment of operational efficiency, different research purposes may result in discrepancies between the selected inputs and outputs. Thus the input and output variables must be chosen carefully. This research used the Pearson correlation coefficient to confirm inputs and outputs. Satisfying the DEA model's "isotropic" assumption (i.e., increasing the number of inputs does not reduce the number of outputs) was adopted as this study's variable for assessing operational efficiency. The key findings include:

1. For the four dimensions used here to evaluate case efficiency, the total efficiency typically averaged more than 0.9. Personnel quality dimension obtained the lowest efficiency score, indicating that personnel quality made little contribution to DMU efficiency. The optimal efficiency for each dimension was found in case DMU09 (operational finance), DMU24 (management system), DMU22 (service quality) and DMU18 (personnel quality).
2. For operational finance dimension, 1.42% of resource wastage stems from technical inefficiency and 3.61% stems from scale inefficiency. For management system, 2.61% of resource wastage stems from technical inefficiency and 1.44 stems from scale inefficiency. For service quality, 5.83% of resource wasted stems from technical inefficiency and 2.92% stems from scale inefficiency. For personnel quality, 2.61% of resource wastage stems from technical inefficiency and 13.45% stems from scale inefficiency.
3. DMU10 ranks among the five most operationally efficient four times for the various dimensions and is considered the benchmark case. DMU23 ranks in the five least operationally efficient three times for the various dimensions and corresponds to the least ideal and most in need of improvement.

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Biography

Wei Tong Chen is a Professor and the Chairman of the Dept of Construction Engineering at YunTech, Taiwan. He received his PhD from University of Florida in U.S.A. Professor Chen is the chief editor of Value Management Journal and Journal of Property Management. A certified AVS of the SAVE International, Professor Chen serves the publishing committee of the Construction Management Association of Taiwan and the Engineering Management committee of the Chinese Institute of Civil and Hydraulic Engineering. Professor Chen offers value engineering courses at graduate school. He is now principally involved in innovative project performance measurement, construction management, construction safety, property management, and value engineering application with an active interest in research. He published more than 150 papers in construction management and property management in last 10 years.

Jien-Bin Jian is the vice president of Guangxi Hhengzhao Real Estate Investment Co., Ltd. He holds a Master of Science degree in Property Management from National Yunlin University of Science & Technology. Mr. Jian has been working on the field of Property Management for several years.

Hong Long Chen (Ph.D., University of Florida) is a professor in the department of Business and Management at the National University of Tainan, Taiwan. His research interests are project finance, corporate finance, performance management, and supply chain management. He is a reviewer of several prestigious journals, such as the IEEE Transactions on Engineering Management, International Journal of Project Management, Supply Chain Management: An International Journal, International Journal of Production Economics, Journal of Management in Engineering, Journal of Construction Engineering and Management, and Construction Management and Economics. He is also a member of the editorial board of International Journal of Information Technology Project Management.