CHAPTER

17

Advanced Models: Data Envelopment Analysis

LEARNING OBJECTIVES *The material in this chapter prepares students to:*

- Understand the characteristics of a good evaluation system.
- Apply the basic evaluation systems and understand their shortcomings.
- Use Data Envelopment Analysis as an evaluation tool.
- Additional technical material is on the student CD.

A key difference between services and manufacturing is the number of the company's facilities and the nature of the work they do. Manufacturers tend to have a small number of facilities that usually make different products. Services often have a large number of units, where each unit does nearly the same task.

For example, General Motors, with year 2003 sales of $196 billion and 326,000 employees, operates 30 fabrication and assembly facilities in the United States and approximately 100 such facilities around the world, with most of those facilities making different types of cars. McDonald's has a similar number of employees, 418,000, but generates about one-tenth the revenues ($17 billion) spread over more than 31,129 sites, where each of those sites strives to produce the same burger and fries. As shown on Table 17.1, many service systems grow to enormous size in terms of units, even though they may not be well known.

The sheer size of many service systems, combined with their geographic dispersion, creates difficulties in assessing performance, which differs from manufacturers. The manufacturer Hewlett-Packard made "management by walking around" famous, a practice in which senior leaders literally walk around among employees to find out how operations are progressing. However, as the number of distinct units within many services increases, it is no longer feasible for a company leader to have first-hand knowledge of what goes on. Sam Walton was famous for his personal approach to management at Wal-Mart, but his firm grew so quickly that even his goals were scaled down to just visiting each Wal-Mart store once in his life.

TABLE 17.1: *Service Companies with Multi-site Operations*

Many companies today operate a large number of retail facilities. Some of these will be familiar. Many will be unfamiliar, even though they have hundreds of outlets!

Company	Number of Sites
Auto-Related	
AAMCO Transmissions	more than 700
Budget Rent-a-Car	3,240
Jiffy Lube	2,156
Meineke Car Care	891
Midas (brake/muffler repair)	2,777
Novus Auto Glass Repair	more than 2,200
Banks	
Bank of America	4,495[a]
Wachovia Bank	2,626[a]
Cleaning	
Coverall Cleaning Concepts	7,085
Jani-King	more than 9,500
Mitex Indoor Hygenics	more than 4,000
Desserts	
Baskin-Robbins (ice cream)	3,460
Dunkin' Donuts	4,736
Tim Horton's (doughnuts)	1,893
TCBY (frozen yogurt)	2,006
Yogen Fruz Worldwide, Inc.	more than 5,000
Fast Food	
Burger King	8,246
Domino's Pizza	5,996
McDonald's	31,129[c]
Subway	17,500
Hair Styling	
Fantastic Sam's	1,350
Supercuts	1,778
Lodging	
Choice Hotels	more than 5,000[b]
Marriott	2,600
Super 8 Motels	more than 2,000[b]
Other	
Carlson Wagonlit Travel Associates	1,121
Dollar General (discount stores)	6,700[b]
GNC (nutrition)	4,811
Heel Quik! (shoe repair)	732
Kumon Math and Reading Centers	1,272
Kwik Kurb (concrete services)	more than 1,250
Merle Norman Cosmetics Studios	2,006
Miracle Ear (hearing aids)	1,103
Pearl Vision (eyecare)	811
Radio Shack	7,113
Snap-On (tools)	4,680
Wal-Mart (discount stores)	4,800[c]

Source: The Franchise Handbook (Spring 2004).

[a] *Source:* FDIC, April 2004.
[b] *Source:* Company Web site. Data as of year end 2003.
[c] *Source: www.fortune.com*, data as of year end 2003.

Typical performance reviews require human judgment. Without firsthand knowledge of the conditions under which a unit operates, however, the usefulness of informal judgment in reviewing performance is limited. Many types of performance review systems are employed in service firms. Within a business curriculum, detailed explanation of those systems is generally covered in a course on organizational behavior. Consequently, most systems will not be discussed in this book. Here, we focus on a relatively new method of performance appraisal and benchmarking used almost exclusively in service firms: Data Envelopment Analysis (DEA).

Formally, DEA is a linear programming technique for measuring the relative efficiency of facilities. However, detailed knowledge or even a comfort level with linear programming is not required to understand how DEA works or to run a DEA system in practice. Along with discussing the theory behind DEA, we will show how to use DEA in spreadsheet software (Excel) and discuss the software vendors available who provide easy-to-use DEA packages.

In managerial terms, DEA is a practical measurement tool for businesses with many different sites performing similar tasks when a single overall measure, such as profit or ROI, is not sufficient.

The next section will describe the general reasons for establishing formal performance review systems and discuss the drawbacks of common systems. Then, DEA will be explored in detail.

Characteristics of Evaluation/ Benchmarking Systems

System Uses

Although the need for some kind of performance measure may seem obvious, the best type of system to implement depends on the goal. Several possible goals are listed in Table 17.2. It is not unusual for a corporation to use several independent performance measurement systems, each satisfying a different need.

A common goal of a performance measurement system is evaluation: determining the good from the bad, assigning pay raises, distributing bonuses, or deciding who gets the next promotion. Rather than the evaluation of subordinate employees within a unit, which is usually done by the unit manager, we are concerned here with evaluating entire units or the manager of a unit. One goal is to separate managerial performance from the performance of a unit. When looking at candidates to determine who gets the promotion to manage the flagship unit downtown, it's important to know whether a top-performing unit is performing well because of or in spite of the unit manager.

A less common but important use of a performance evaluation system is resource allocation; determining which unit gets extra personnel or equipment, which unit receives more or less budget money, or, when corporate needs require it, which units are closed.

Another use of performance evaluation systems is simply classification; determining the best units for either public recognition, or identifying better or worse performing units for finding best practices for the firm, or in order to send trainees to appropriate environments to learn good technique.

Common Performance Measures

At first glance, talk of which yardstick to measure unit performance by seems odd, when simple unit profitability seems the obvious choice. Of course, for nonprofit businesses, profitability is not a particularly good measure. But even in for-profit businesses, individual unit profitability runs into several problems as a measure.

For many businesses, true unit profitability is difficult to measure, on both the cost and revenue sides. Cost measurement can be difficult if many small service units

TABLE 17.2: *Characteristics of Performance Evaluation Systems*

Uses	**Measures Commonly Used**
Evaluation	*Profit*
Units	*Sales volume*
Employees	*Contribution margin*
Resource allocation	*Customer service*
Rationalize personnel/capital	*Market share*
Expense control	
Unit closure	**Methods**
Classification	*Comparison to negotiated goals*
Recognition/reward	*Outputs*
Identification	

of the same firm share employees, inventory, or equipment as needed. Although it is possible to parse out the costs between units, actually doing so requires detailed paperwork and does not send a team-oriented message to unit management. Many costs are temporary or provide unfair disadvantages. For example, due to alleged price manipulations by Enron and others, electricity costs in the summer of 2001 for a hotel in California were several times higher than for a hotel in New Hampshire. Therefore, to say the California hotel manager performed worse than the New Hampshire manager due to a temporary imbalance beyond managerial control would be inappropriate. Also, a large cost for many service units is occupancy or land/space rental. Due to the nature of long-term leasing agreements or the changes in price of purchased land, a unit may be highly profitable or unprofitable largely due to real estate values. This measure may tell a company that the land underneath the unit should be sold, but it does little to inform a company of the value of the manager of the unit.

Revenue measurement can also be difficult in industries that share customers between units. In banking, for example, the profitability of a checking account is customarily assigned to the bank branch that opened the account. The problem with this arrangement is that a given customer may, for example, open an account near her home, but use the branch closer to her office for bank services. Consequently, the branch of account gets all the revenue while the other branch gets all the expense. This problem is a significant one in banking. A First American Bank study indicated that, on average, only 20% of customer branch transactions occurred at the branch that opened the account.

Profitability also is problematic as the sole measure of performance because it fails to tell the whole story. If a unit is trying to build market share, current expenses are quite often higher because of this effort. Also, an easy way to manipulate current profit numbers is to skimp on service. Laying off or hiring low wage, inexperienced employees will help the current period financial results, but it can lead to poor customer service that will hurt the bottom line in the future.

Because of these difficulties with profitability as a measure, other considerations such as sales volume, contribution margin, customer service, or market share also are often considered in the evaluation process.

Common Evaluation Methods

Many common evaluation techniques exhibit several weaknesses that DEA does not share.

1. They rely on a comparison to negotiated goals, which can reward counterproductive behavior.
2. They involve just viewing results without a consideration of resources used to get those results.
3. The weights used to combine different measures are subjective.
4. Performance criteria do not adjust quickly to changing environments.

Managers are often compared to negotiated goals. A problem with this method is in how the goals are set. One way to set goals is to compare them to the previous time period: “Your goal for this year is last year plus 10%.” Unfortunately, this approach encourages bad behavior, such as shirking and sandbagging. A poor performer who shirks her duties can increase output by merely shirking a little less next time around, while a great performer always has her bonus tied to her great performance last year. Further, once someone makes that “last year plus 10%” goal, an

incentive to sandbag or cease working arises at that point, because an employee knows that having unusually good results today will only be penalized through higher goals tomorrow.

In a multi-site firm, service goals are often set for unit managers by regional or national staff. But staff members may meet unit managers infrequently and know only limited information about the difficulties of particular local neighborhoods. The two problems with this approach include a tendency to focus solely on results, rather than results per resource used, and the goal-setting process used to account for local problems.

If local differences are taken into consideration in goal setting, it is usually up to the unit manager to make a case for specific goals by pointing out local conditions and negotiating appropriately. Consequently, it can be the case that the successful unit manager is one who negotiated goals successfully, rather than managed a unit well.

To get around such biases in negotiated goals, it is tempting to look only at results: How much money was made, what market share is, and so on. Results alone, however, often do not truly reflect how well someone is doing her job. A mediocre manager might get good results from a unit in a great location, while a great manager may only get mediocre results from a unit in a bad location.

Finally, once performance measures and goals are agreed upon, another difficulty is figuring out how to combine them. Often, in the end, only a single decision needs to be made, such as whether to give a raise of 10% or 5% or whether a specific unit should be closed or kept open. The information, in the end, must be reduced to a single decision, but figuring out the formula is difficult. How much accounting profit is worth a 0.2 point increase in customer satisfaction? How much profit now is a 2% market share increase worth? In most performance evaluation systems, managers supply percentages of the overall evaluation to different categories, but those managerially supplied percentages often seem capricious, or fit one situation but not another. A manager who says, "I don't know how to weight these things, so I'm not going to weight them at all," only compounds the problem. The true meaning of "not weighting" items on a list usually means giving them all equal weight, which is, of course, a weighting system unto itself.

Advantages of Data Envelopment Analysis

The purpose of this chapter is to introduce DEA as a performance evaluation method for multi-site services. The advantages of DEA over traditional, more subjective methods include the following:

- *Data reduction:* DEA output reduces multiple performance measures to a single number.
- *Objectivity/fairness:* The weighting of performance measures is carried out by a known algorithm.
- *Personalization:* The weighting of performance measures reacts to the individual unit; that is, weights are different from unit to unit depending upon their special characteristics. As described in more detail later, weights are chosen by DEA for each unit that will make that unit look the best.

Rather than comparing units to negotiated goals, DEA compares units to the actual results achieved and resources used by other real units. This aspect gives DEA the following advantages over goal-based methods:

- *Environmental change response:* If the economy, or any other important uncontrollable factor, unexpectedly goes up or down, goal-based measures must be

readjusted, and readjusting someone out of his annual bonus is rather unpopular. Because DEA takes into consideration only actual results, factors affecting everyone will not affect results.

- *DEA doesn't reward sandbagging, nor does DEA punish superior performers:* Again, because one is compared to peers rather than a personal history, stellar management is not penalized for results that are great, but not as great as last year.

DEA is not suited to all multi-site firms. It is best suited to firms with "results ambivalence," result measurements that are not easily combined, and units that provide similar services and have similar competitive goals. These conditions are explained here.

If it is unquestioned that, for example, a unit profitability statement is clearly the only result that matters, DEA is probably not the best technique. If profitability, market share, customer satisfaction, among other factors, are all important, that is, if some ambivalence remains as to the specific results that are important, then DEA can be helpful.

DEA combines numbers that do not ordinarily add up well. For instance, DEA does well in combining that 0.2 customer satisfaction rating increase mentioned earlier with market share percentage information and financial results.

Also, DEA is best suited to comparing units with similar goals. DEA would not work well if the units being compared were plants that assembled Corvettes, SUVs, and minivans. As will be explained later, the math behind DEA works best when a large number of similar units share similar goals.

The Concept of DEA

DEA can be applied to such diverse fields as public school educational programs, courts of law, hospitals, school busing, baseball player salaries, oil and gas production, vehicle maintenance, retail stores, mining, and bank branches. There have been over 1,800 academic publications regarding DEA (Gattoufi, Oral, and Reisman, 2004). Table 17.3 lists some firms that use DEA. Note the large number of consulting firms on this list. In addition to being a tool a corporation can use in a routine reporting manner, DEA provides an especially valuable tool for project consulting.

A number of prominent, successful applications of DEA testify to its many strong points. However, this chapter is not meant to be an advertisement for the

TABLE 17.3: *A Sample List of Corporate Users of DEA**

AMEC Offshore Development	Integrated Decision Systems, LDA plc
Ameritech	Libraries Unlimited
Banca Populare di Milano	Midlands Electricity Board
Bank of Scotland	Mitomo Co, Ltd, M2L
Boston Consulting Group	PricewaterhouseCoopers
British Gas Transco	S.H.C. (Switzerland)
CalEnergy Company Inc.	Securities & Exchange Comm. (Thailand)
Carlson Marketing Group	Strategic Leadership Sciences (Europe)
Commonwealth Bank (Australia)	Syndactics Inc.
CountryWide Banking Corporation (Australia)	The Boston Company
CREG (Colombia)	U.S. Air Force
DERA	USA Defense Logistics Agency
Direct Line Insurance	Whitbread plc
EIS, GSW	World Bank
Guy's Hospital (London)	Xuzhou Hospital (Peoples Republic of China)

*Partial list of Banxia "Frontier Analyst" software users.

technique. Because the technique can be a confusing one, a number of inappropriate applications are possible as well. Users of DEA must guard against its drawbacks. First, the technique will be explained, then extensions to the basic technique and problems will be discussed.

DEA combines numerous relevant *results obtained* (called *outputs* by DEA professionals) and the *resources* used to create those results (called *inputs*) into a single number that represents the *productivity* (called *efficiency*) of using resources to create results.

The basic thought that DEA is trying to project is:

$$\text{Performance} = \text{results obtained/resources used}$$

Or, in "DEA-speak":

$$\text{Efficiency} = \text{outputs/inputs}$$

A DEA report will show a single number ranging from 0 to 1 that rates the performance, or efficiency, of whatever is being reviewed. An efficiency rating of 1 means that the unit rated is fully efficient—the best among the group at what it does. A rating less than 1 means a unit is inefficient at producing results from the resources it has. As shown graphically, the amount of inefficiency can be physically and geometrically interpreted. An efficiency of 0.90 means that the performance of the unit is physically 90% of the way to being fully efficient.

For each unit that is being measured, a DEA program finds weightings for results and resources used to solve the following general problem:

Maximize:

$$\text{Results} \times \text{a weighting for each result for a specific unit}$$

provided that

$$(\text{results} \times \text{weighting})/(\text{resources} \times \text{weighting}) \leq 1$$

for all units in the system, and

$$\text{resources} \times \text{weighting} = 1$$

for the specific unit being rated.

Or, in the more typical language of those who use DEA, one of the linear programming formulations is[1]:

$$\text{Maximize outputs}_j \times \text{output weight (specific unit } j) \tag{17.1}$$

s.t. (subject to)

$$(\text{outputs}_i \times \text{output weight}) - (\text{inputs}_i \times \text{input weight}) \leq 0 \text{ for all units } i \tag{17.2}$$

$$\text{inputs}_j \times \text{input weight} = 1 \text{ for specific unit } _j \tag{17.3}$$

$$\text{input weight, output weight} \leq 0 \tag{17.4}$$

In plain English, what is meant to be done in DEA is to find the most favorable weights for every unit, given the results and resources used of all other units, so that the performance of a given unit will be as high as possible, with "1" being the highest possible performance.

1. Of the several different types of DEA formulations, the one presented here is called an "output oriented, primal" formulation because it maximizes outputs for a given level of inputs and relates to the linear programming "primal" formulation instead of the "dual" formulation. Similarly, one can have an "input orientation," where the formulation is to minimize the resources used for a given level of performance. A good reference listing a variety of DEA models is Charnes et al. (1994).

One of the intriguing aspects of DEA is that no a priori weighting of outputs or inputs is assumed. Every unit gets full credit for doing what it does best. The thinking is that if the "results ambivalence" assumption is true and all the results being measured are important to the company, it doesn't matter how a unit makes its contribution. An easy way to visualize this concept is through an example from the world of sports. A football team needs players who can pass, catch, run, tackle, and so on. But if they chose players on a strict weighting of, say, 30% passing, 20% blocking, 50% running, one can imagine that winning games would be a challenge. A team composed of people who are merely good at specific positions would easily defeat a team composed solely of the greatest quarterbacks to play the game.

Park Cities Bank and Trust: A DEA Example Problem

Assume that the only relevant measure for a retail bank branch is profitability, and profit is entirely determined by loan and deposit balances. Unfortunately, even with that simplification the task of determining good and bad performers is not easy. Due to factors beyond the scope of this text, the actual amount of money earned every year on loan and deposit portfolios can vary widely. In some years, loans are highly profitable whereas deposits are marginally so, in other years the reverse is true. If measured on profit alone, branches that are good at generating checking accounts may be viewed as excellent branches one year and poor performers the next, even if they are performing at a sustained level of excellence in generating deposits. Consequently, a gross profit number based on specific profit margins that can change may not be appropriate.

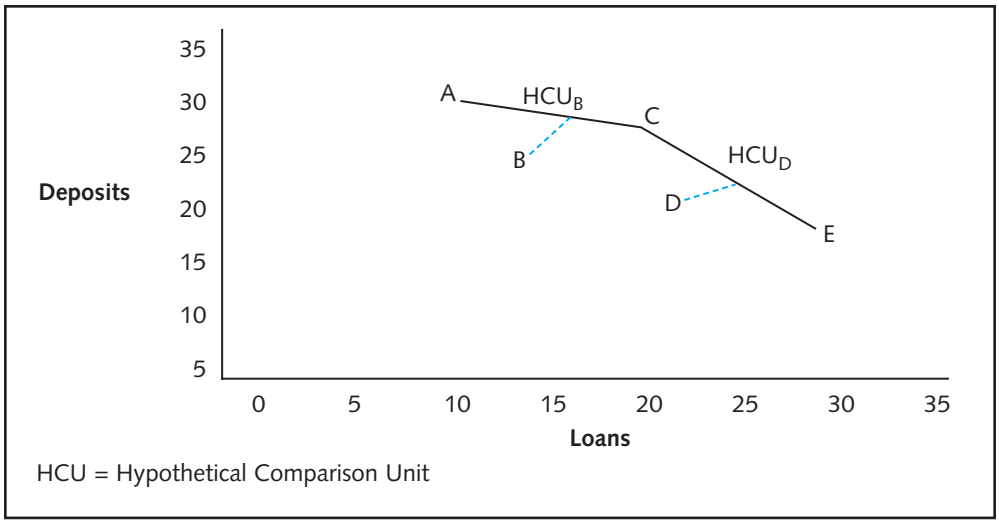
DEA takes a different approach. Essentially, DEA combines the two balances (loans + deposits) using every possible ratio of profit margins and chooses the set of loan and deposit margins that are most complementary to the branch being evaluated. After choosing such a set of loan and deposit margins for each branch, the DEA program rates the efficiency of each branch on a scale of 0 to 1.

Table 17.4 shows five potential levels of the Park Cities Bank's branch performance, which are reproduced graphically in Figure 17.1. Table 17.4 lists identical inputs of 100 for each branch and separate outputs of loans and deposits. Inputs can be construed as personnel, total expenses, and so on. Branches A, C, and E show the highest efficiency rating of 1 and are deemed efficient; that is, no other branches outperform them on both measures. In terms of profits, the efficiency rating of 1 means that there is a pair of profit margins on loans and deposits on which each of those branches would be the most profitable branch in the system. Note that these are "relatively" efficient branches—relative to the other branches in the system. DEA defines which branches are the "best practice" branches in a system, which does not necessarily mean they can beat the competition.

TABLE 17.4: *DEA Evaluation of Park Cities Bank Branch Performance*

Branch	Inputs	Loans	Deposits	Efficiency
A	100	$10	$31	1
B	100	15	25	0.83
C	100	20	30	1
D	100	23	23	0.92
E	100	30	20	1

FIGURE 17.1: *Park Cities Bank DEA Efficient Frontier*



HCU = Hypothetical Comparison Unit

Note that branch A is deemed efficient even though it generated far fewer loans than branch C and only minimally larger deposits. Even more extreme, a branch with $1 more in deposits than branch A and a total of $0 loans would also have an efficiency of "1." It is efficient in the same sense that Pareto efficiency is viewed in traditional economic theory, where the efficient frontier represents the trade-off curve in the classic production function or consumer indifference curve. Consider how such a branch could be an "efficient" performer in practice: If loans were a "loss leader" and had a negative profit margin, a branch with lots of deposits and no loans would be a star.

For branches B and D, however, no possible loan/deposit margins would cause these branches to be the most profitable. For branch B this is easily seen, as it is "dominated" by branch C; that is, branch C performs better on both dimensions than branch B. As the number of outputs and inputs increases, a dominant relationship such as the one between branches B and C becomes less likely. Consequently, direct comparisons become less useful and the need to use DEA increases. Further, once a two-output scenario is exceeded, the intuition and graphical analysis that guide the preceding example fail and the data reduction afforded by DEA becomes more valuable.

The case of branch D demonstrates a nondominated unit. No other branch dominates branch D on both dimensions. For nondominated branch D, DEA creates a Hypothetical Comparison Unit (HCU) that is a linear combination of efficient units. In this case, the HCU_D is composed of a melding of branches C and E and would represent a point of (25, 25) on Figure 17.1. The HCU_D of (25, 25) is the point on the efficient frontier one would hit if a line were drawn from the origin, through branch D, to the frontier. A line with one endpoint is called a *ray*, consequently, it is known as radial efficiency. The efficiency measure is geometrically interpreted: Branch D is 92% of the distance from the point (0,0) to the HCU on the efficient frontier. The HCU corresponding to branch B is (18.1, 30.2), leaving branch B with an efficiency of 83%.

DEA gives more information than just efficiency scores. For inefficient units, merely being told that "your efficiency is 70%" is not particularly helpful. The typical output of a DEA model also provides information on what must be improved by

how much to become efficient, and information that is called a *reference set* for a unit. The reference set of a unit is the group of efficient units that the inefficient unit is most like. For example, in Figure 17.1, the reference set for branch B would be branches C and A. In essence, this information gives a manager a list of mentors that are similar to that unit, but do a better job.

To show exactly how these calculations are made, the specific model of equations (17.1) through (17.4) for branch B follow. Recall, the variables solved for in the model are "loan weight" and "deposit weight." (The numbers in the following model come from Table 17.4.)

Branch B Analysis

$$\text{Maximize } 15 \text{ loan weight} + 25 \text{ deposit weight} \quad (17.5)$$

s.t.

$$10 \text{ loan weight} + 31 \text{ deposit weight} - 100 \text{ inputs} \leq 0 \quad \{\text{Branch A}\} \quad (17.6)$$

$$15 \text{ loan weight} + 25 \text{ deposit weight} - 100 \text{ inputs} \leq 0 \quad \{\text{Branch B}\} \quad (17.7)$$

$$20 \text{ loan weight} + 30 \text{ deposit weight} - 100 \text{ inputs} \leq 0 \quad \{\text{Branch C}\} \quad (17.8)$$

$$23 \text{ loan weight} + 23 \text{ deposit weight} - 100 \text{ inputs} \leq 0 \quad \{\text{Branch D}\} \quad (17.9)$$

$$30 \text{ loan weight} + 20 \text{ deposit weight} - 100 \text{ inputs} \leq 0 \quad \{\text{Branch E}\} \quad (17.10)$$

$$100 \text{ inputs} = 1 \quad \{\text{Inputs} = 1\} \quad (17.11)$$

An Excel spreadsheet containing this example can be found on the Student CD.

Access your Student CD now for an Excel worksheet continuing this Branch B calculation.

DEA Implementation Problems

Many DEA implementations fail. Some general guidelines are helpful in utilizing DEA.[2]

Complexity

DEA is simply hard for many people to understand. Despite the graphical nature and interpretation of the output, and the ease of use of DEA software, practitioners find it confusing and are often uncomfortable when their raises depend on this inscrutable technology. For this reason, DEA is often better used simply as a means of classification, benchmarking, or finding reference sets and possible paths of improvement than it is for determining raises or bonuses.

Size Matters

At some point, when the number of outputs and inputs is large and the number of units being looked at is small, mathematically every unit will become efficient. Because of this excess of outputs and inputs, more than half of the branches obtained the highest efficiency rating in prior studies of bank branches. Although these studies may placate branch managers, they are not helpful to senior management for decision-making purposes. A judicious choice of outputs and inputs retains the power of DEA but limits the number of branches that will attain the highest rating. Consequently, a "rule of thumb" says that no less than twice as many units should be considered as there are inputs and outputs combined.

2. For a more robust and technical treatment of this issue, see Metters, Frei, and Vargas (1999), and Dyson et al. (2001).

Ambivalence Regarding Outputs

In the example given previously, DEA makes sense only in the case of ambivalence as to whether a branch generates deposits or loans. In the broader context, in a strong hierarchy of strategic goals, where one goal is clearly preeminent, DEA is not useful.

It would be highly unusual to be ambivalent among all strategic goals. Some goals are normally more important than others. In the DEA formulation used in the example problem, branch A was efficient even though its loan balances were far too low. The basic DEA formulation can be easily changed to reflect the reality that branch A is not a top performer. Limits can be placed on the amount of efficiency that can be generated from any one output. If say, a limit of 70% of the efficiency rating can come from any one output, branch A would no longer be deemed efficient. (See section "Adapting DEA to Managerial Concerns.")

Access your Student CD now for information on adapting DEA to managerial concerns.

Spurious Efficiency

DEA looks at every possible ratio of outputs to inputs to give a unit the highest efficiency possible. Sometimes this function results in a false, or spurious, efficiency. For example, consider a poorly performing bank branch that does a lot of transaction processing, but little else, and does that poorly. Because loan origination is not the strategic branch focus, only one loan officer works in the branch. Let us say the branch performs poorly on both transaction processing and loan origination, and that "transactions processed" is a DEA output and "loan officers" is an input. Despite poor performance, this branch might appear efficient because the ratio of transactions processed to loan officers is the best in the network, which is not a reasonable measure on which a firm would like to base performance evaluations.

Employee Gaming

DEA is susceptible to "gaming" by managers just as with many other performance evaluation systems. This vulnerability specifically relates to the previous point on spurious efficiency. Following the example in the prior paragraph, if a manager knows that the efficiency score can be influenced by nonsensical ratios, the manager may take action to manipulate those ratios.

Access your Student CD now for a description of how to do DEA in Excel as well as other DEA software.

Technical Material on Student CD

The following written material can be found on the student CD:

- a description of how to do DEA in Excel as well as other DEA software
- mathematically adding restrictions to the weights in a DEA problem
- more graphical interpretations of DEA (by Ken Klassen, Brock University)

Summary

This chapter focused on the more narrow topic of DEA formulation and implementation. In the broader view, DEA can be a useful managerial tool, but only under the proper circumstances. Foremost, applicability depends on numerous units that attempt roughly the same task where the firm has true goal ambivalence. If diverse units are input, the exercise will be futile because all the branches will appear equally efficient. For example, due to the mathematics of DEA, if only one branch made mortgage loans and mortgage loans were an output, that branch would be efficient regardless of its other characteristics.

The first uses of DEA were concentrated in the nonprofit sector. The multiple outputs and goal ambivalence inherent in the nonprofit sector appropriately fit the DEA methodology. Any transfer of this technology to the for-profit sector must also find an environment where a single measure of productivity or efficiency is not recognized. When multiple measures are appropriate, however, DEA is a superior technique to the standard business practice of analyzing ratios at an individual level. Performance reviews based on standard ratio analysis encourages managers to increase some measures at the expense of others. DEA—when performed properly—evaluates the entire package of inputs and outputs to assess unit performance.

Review Questions

1. What are the benefits and disadvantages of traditional evaluation measures such as unit profits or goal-based performance measurement?
2. What are the required business conditions for using DEA?
3. What are the benefits and disadvantages of DEA?
4. What is "results ambivalence," and why is it important?
5. What is the purpose of the "Hypothetical Comparison Unit?"
6. Why is the reference set a useful managerial tool?

Problems

17.1. University faculty are often evaluated and promoted based on two main criteria: Teaching and research. At many of the "research" schools, a rough weighting may be 80% research, 20% teaching. What would be the benefits or disadvantages of rewarding faculty based more on a DEA-like weighting of research and teaching? That is, allowing individual faculty to choose the weighting that suits them the best?

17.2. Consider a DEA analysis of many units of a firm with two outputs and two inputs. Unit A has outputs of 110 on Output 1 and 140 on Output 2 with inputs of 170 on Input 1 and 1,050 on Input 2. Unit B has outputs of 100 on Output 1 and 70 on Output 2 with inputs of 190 on Input 1 and 1,500 on Input 2. Even without knowing the data from the other units in the firm, could either of these units be efficient?

Access your Student CD now for data for Problems 17.4 through 17.7 in Excel worksheet form.

17.3. (This problem can be solved using pen and paper only.) The multi-site service units in Table 17.5 have two outputs, profit and a customer satisfaction rating, and one input called, well, "input." Which of the service units would be called efficient by DEA?

17.4. The data in Table 17.6 depict two outputs of "margin" and "market share" and one input of "payroll." Find the efficiencies of units 1–4.

TABLE 17.5: *Data for Problem 17.3*

Unit	Inputs	Profit	Customer Satisfaction Rating
A	10	14	8.2
B	5	9	3.8
C	10	–5	8.3
D	10	20	7.0
E	10	10	7.8

TABLE 17.6: *Data for Problems 17.4 and 17.5*

	Margin	Market Share	Payroll
Unit 1	18.0	14.1	125.9
Unit 2	12.2	15.9	136.4
Unit 3	14.1	19.2	132.8
Unit 4	16.5	14.2	132.3

17.5 For the data in Table 17.6, if "market share" were restricted to providing only 20% of the total efficiency, what would the efficiencies of units 1–4 be (i.e., "market share" × market share weight ≤ efficiency × 0.2)?

17.6. Based on the three outputs and three inputs in Table 17.7, find the efficiencies of units A–J.

17.7. For the data in Table 17.7, if "sales growth" were restricted to providing only 20% of the total efficiency, what would the efficiencies of units A–J be (i.e., "sales growth" × sales growth weight ≤ efficiency × 0.2)?

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TABLE 17.7: *Data for Problems 17.6 and 17.7*

	Outputs			Inputs		
	Margin	Sales Growth	Market Share	Logistics Cost	Rent	Payroll
Unit A	18.0	25.7	14.1	155.3	81.5	125.9
Unit B	12.2	20.6	15.9	174.8	78.1	136.4
Unit C	14.1	20.6	19.2	168.6	82.1	132.8
Unit D	16.5	22.2	14.2	162.9	82.5	132.3
Unit E	14.6	22.1	15.7	166.1	87.2	130.4
Unit F	14.0	20.1	14.0	169.4	87.2	132.9
Unit G	15.1	19.8	13.6	167.1	81.1	130.4
Unit H	17.2	21.3	15.3	160.7	83.2	129.2
Unit I	14.9	18.0	14.1	168.8	83.9	133.8
Unit J	15.6	14.4	16.0	169.8	81.8	129.9

CASE STUDY

Branch Performance at Nashville National Bank

Julie Moore, Senior Executive Vice President and Chief Operating Officer of Nashville National Bank (NNB), sat at the helm during a time of rapid expansion that saw NNB grow from three to ten branches in a few years. Unfortunately, that expansion is now responsible for some personnel problems. Many of the branch managers are complaining loudly about discrepancies in pay, titles, and resources. One older branch manager who recently received an unfavorable performance review threatened to sue NNB for age discrimination if he was fired.

The complaints focused on the branch performance appraisal process. Determining some measure of bank branch performance is essential. Without some agreed-upon performance measure, varied decisions such as branch expansion/closure, managerial promotion, and resource allocation are left to the "feel" of senior management. Currently, Julie gave all branch manager performance reviews herself. Being a "hands-on" type of manager, she felt that she was in an informed position to pass judgment on each branch. She based her judgments on what she feels each branch should have accomplished during the past year, given their location and past performance, but used no particular benchmark.

During the mid 1990s, when the bank operated only three branches and she knew each manager well, her informal style seemed to work well. With the complexity of a larger branch network, combined with the political factions arising within it, she realized that a more formal approach was necessary. Under her informal evaluation system, many managers felt that the negotiating and presentation skills of branch managers can be a more important input to their performance appraisals than the actual performance of their branch.

Julie decided to compare the formal branch performance evaluation systems that peer banks use to see if one would fit at NNB.

Branch Growth at Nashville National Bank

NNB was founded in 1980 as a largely retail bank serving upper-middle class customers in Nashville. Nashville, Tennessee, has a population of 570,000, while the encompassing Standard Metropolitan Statistical Area has a population of 1.2 million, making it approximately 35th on a list of the largest metro areas in the United States. NNB had only three branches within Nashville when it merged with a failed thrift, Belle Meade S&L, in 2003, and gained three more branches. The Belle Meade area in Nashville is the wealthiest section of town. In 2004, NNB purchased another failing institution, Farmer's Bank, located in more rural Robertson County, which added one branch. Last year NNB and People's Bank, with three branches in suburban, middle-class communities south of Nashville merged, bringing the total branches in the NNB system to ten.

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Each of the acquisitions was made because the banks were considered "good buys," rather than for strategic considerations. Outwardly the branches underwent few changes. The employees of the purchased banks were kept on at their current pay scale and title. Few procedural changes were made to make them conform to NNB's methods. For instance, loan application and review were different from branch to branch. At the extreme, only the former Farmer's Bank branch made agricultural loans.

The major changes at NNB occurred in the backroom operations. The most significant change was to the computer systems. Each of the disparate systems was integrated to ensure that accounts could be accessed in real time from any branch in the NNB system. This capability was greatly appreciated by their customers. Many customers preferred to process transactions at a variety of branches in the NNB system, not just the particular branch that opened their account.

The acquired branches catered to different market segments than NNB traditionally embraced. Belle Meade S&L focused on retail banking for the higher-income local customers. Farmer's Bank provided both retail and commercial services for agricultural purposes. As agriculture declined in importance in the local economy, the market share of Farmer's commensurately decreased. People's Bank provided retail services to a basically middle-class clientele.

Assessing Branch Productivity: Available Techniques

Although it is clearly necessary to implement some measure of branch performance, considerable disagreement surrounds what should be measured and how to measure it. A wide variety of measurement and reporting techniques are currently used by different banks to evaluate branches.

Julie narrowed the choice of alternatives to three commonly used techniques: branch profitability, branch ranking and branch goals, and one emerging technique used only recently—Data Envelopment Analysis (DEA).

- **Branch Profitability.** Many banks evaluate branches by fashioning financial statements for each branch. Interest and fee income from accounts is credited to the branch where the accounts originated. This income is netted against interest costs and noninterest expenses to determine a profitability level (Table 17.8).
- **Ranking Reports.** An alternative is to evaluate branches according to performance in specific areas separately, rather than using a single profitability number.
- **Goal Reports.** Preset goals are negotiated with each branch manager on a variety of topics. Performance evaluation is based on the percentage of goals attained. The categories used for goal reporting would be similar to those used in ranking reports.
- **Data Envelopment Analysis (DEA).**

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TABLE 17.8: *Branch Profitability Financial Statement*

Sample Branch Profitability Statement
($ in 000)

	September 1999
Interest Income from Loans[a]	384.2
Federal Funds Sold[b]	0.0
Total Interest Income	384.2
Interest Expense from Deposits[a]	(185.5)
Federal Funds Purchased[b]	(23.0)
Total Interest Expense	(208.5)
Provision for Credit Losses	(26.5)
Net Interest Income After Provision for Credit Losses	149.2
Noninterest Income	
Deposit Account Fees	22.2
Loan Fees	12.1
Total Noninterest Income	32.3
Noninterest Expense	
Salaries	(35.0)
Benefits	(7.4)
Occupancy	(4.1)
Other Expense	(18.2)
Total Noninterest Expense	(64.7)
Net Income Before Support Expenses	116.8
Specific Support Expense[c]	(32.6)
Net Income Before General Expense	84.2
General Support Expense[d]	(22.4)
Net Income	61.8

[a] Income/expense from loan and deposit accounts initially opened by branch.
[b] If more deposits are taken in than loans given out, the excess is sold on the Federal Funds market. If excessive loans are granted, the money is borrowed from the FF market.
[c] Expenses of central administration directly related to branch activity.
[d] Expenses of central administration not directly related to any specific branch (e.g., president's salary).

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Branch Managers Revolt

The problem of evaluating branches was brought to the forefront by the former People's Bank managers. They knew their titles were of lower rank than other branch managers, but they believed that it was due to the merger process and that salaries were relatively equal. When they inadvertently discovered the wide gaps in salaries between branch managers they were furious (Table 17.9). The former People's managers demanded that Julie bring their titles and salaries up to the level of the other managers.

John Semple, the president of NNB, was against any pay increases. He believed that the former People's branches were not producing as well as the others and that their managers should be paid accordingly. Realizing that his "feel" was not going to be good enough to placate the branch managers, he instructed Julie to come up with an objective method of determining how well the branches were doing.

Julie's Folly

Julie decided to use DEA to evaluate the NNB branch system. She used five outputs and three inputs. The outputs chosen were branch profit, a deposit transaction index, a new account index, an existing account index, and agricultural loan balances.

Branch profitability was calculated as shown in Table 17.8. Julie used the average monthly profit for the last three years. The other measures are combined indexes of many items. The transaction index multiplies the number of transactions handled at a branch by the standard time required to perform the transaction. For example, handling a routine deposit takes 20 seconds, but writing a cashier's check

TABLE 17.9: *Branch Manager Salaries*

Original Bank	Branch Number	Branch Manager Title	Branch Manager Salary
NNB	1	Vice President	$58,000
NNB	2	Vice President	$62,500
NNB	3	Senior V.P.	$75,000
Belle Meade	4	Vice President	$60,000
Belle Meade	5	Senior V.P.	$70,000
Belle Meade	6	Vice President	$56,000
Farmer's	7	Vice President	$62,000
People's	8	Assistant V.P.	$48,000
People's	9	Assistant V.P.	$46,000
People's	10	Assistant V.P.	$44,000

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takes 3 minutes. The branch with the largest amount of standard time was given an index value of 100 and the other branches were indexed accordingly.

Similar procedures were used for new and existing accounts. A certificate of deposit for $10,000 at 5.5% interest is far less profitable than a regular savings account with a $10,000 balance at 3.0%. Consequently, indexes using approximate profitability ratings were used to weight new and existing account activity.

Finally, at the specific request of the Farmer's branch manager, Julie also included agricultural loan balances as an output.

For inputs, Julie used the average personnel and total branch expenses over the past three years. Also, some locations were clearly better than others and branches located in prime spots would reasonably be expected to perform better so a "location desirability" estimate was included as an input.

According to Julie's calculations, nearly every branch was perfectly efficient and of the three that had less than 100% efficiency, the lowest efficiency was 92% (a sample calculation appears in Figure 17.2, results are in Table 17.7). The inescapable conclusion was that the former People's branch managers were right: They were underpaid.

When Julie presented her method and conclusions at the next Executive Operating Committee meeting she was met with a less than enthusiastic response. When she finished, a stony silence ensued and Julie noticed that John was staring down at the desk with his head in his hands.

Vicente Vargas, senior vice president and head of the check-processing center, was the first to speak. "This is garbage. John, give me three days and I'll give you something you can use." When Julie began to protest, John interrupted, "Julie, leave the room. I'd like to hear what Vicente has to say."

Questions:

1. What are good characteristics of evaluation methods in general?
2. What are the strengths and weaknesses of each of the available techniques for measuring bank branches?
3. Specifically, is DEA a good choice for NNB?
4. Construct a superior DEA model. Report the efficiencies for each branch.

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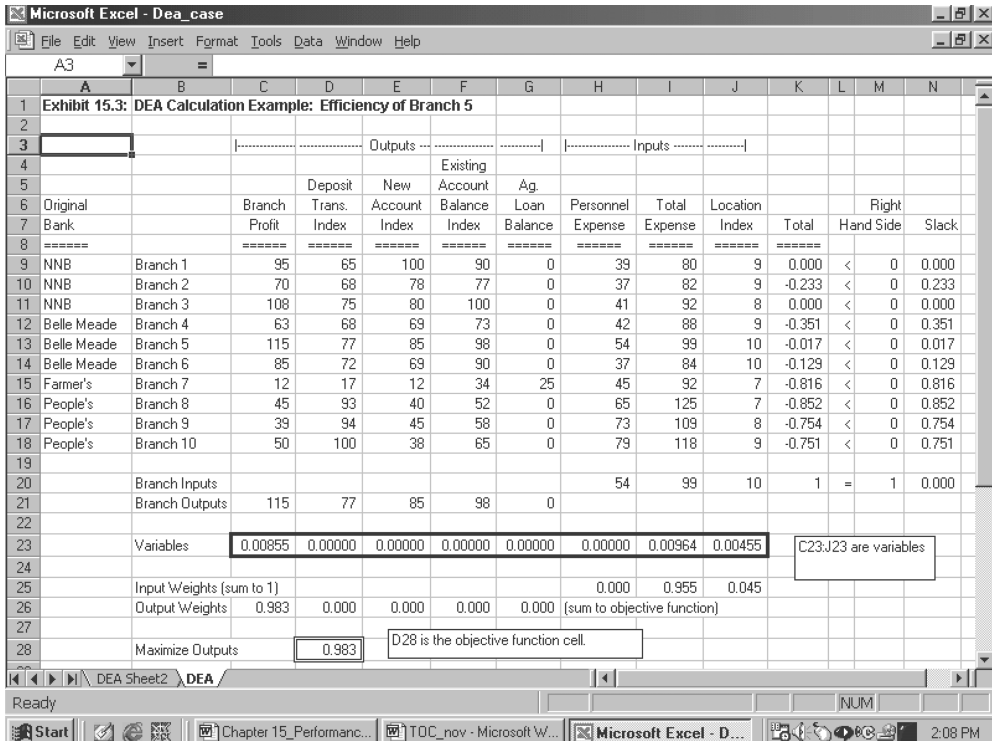
FIGURE 17.2: *DEA Example Calculation*



Access your Student CD now for the Branch 5 DEA Calculation Excel worksheet.