

Foreword

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As the title suggests, this is a book on uses of DEA (Data Envelopment Analysis) to evaluate performances of firms in the service industries. It is more general than this, however, and better described as a user friendly introduction to DEA with examples in the service industries that can help a potential user evaluate DEA for applications that might be of interest. The applications in this book are accompanied by explanations and advice on what needs to be done to ensure success in uses of DEA.

As an introductory treatment, the book begins with a review of established methods that are already available and widely used for evaluating performance efficiencies and effectiveness. The topics covered include accounting techniques such as the use of standard costs with associated “red” or “black variances” that signal deviations below and above “efficient” performances. The discussions extend to the use of “balanced score card” approaches to determine the “effectiveness” of performances relative to goals established for programs intended to implement a corporate strategy. One shortcoming of all of these methods is that they tend to be “one at a time measures” – as is also the case for customary ratio measures such as “return on cost” or “return on net worth,” etc.

By contrast, DEA simultaneously considers all inputs and all outputs that may be of interest and arrives at an overall efficiency or effectiveness score. Moreover, this is accomplished by evaluating the performance of each entity relative to a collection of entities in ways that extend commonly used “benchmark” procedures. In this way DEA identifies a subset of entities best designed to serve as benchmarks for each entity and uses them to evaluate its performance. This results in overall scores such as “90% efficiency,” which means

that the evaluated entity is 10% short of what it should have been able to accomplish. However, this overall score is only one aspect of what is revealed in the DEA solutions. Among other things, the sources and amounts of inefficiency in each input and output are also revealed so that a path to achievement of full (100%) efficiency is thereby obtained.

The mathematics underlying DEA models and their uses is kept to a minimum in this book. Only one of the several DEA models is formulated mathematically. The DEA literature refers to this model as the CCR (Charnes, Cooper, Rhodes) version of an “envelopment model.” This name derives from the way the model “envelops” the data in order to locate a frontier where the best (i.e., 100% efficient) performers are located. This frontier is then used to evaluate the performances of other entities.

To each such envelopment model there is an associated “dual” model referred to as the “multiplier” model. This model provides further information in the form of “weights” assigned to each input and output. These weights are referred to as “multipliers” in the DEA literature in order to emphasize that they are not preassigned values like the weights customarily used in the construction of index number of prices, productivities or cost, etc. That is, the weights in DEA are determined from the data by this multiplier model for each of the entities that is evaluated.

Sherman and Zhu make extensive use of this dual (multiplier) model to increase the possibility of successful use of DEA. For example in addition to the efficiency scores, these weights can be reported for management review where it may be found that the weight assigned by the model to output A, for example, exceeds the weight assigned to output B. If this is not satisfactory it can be dealt with in a manner that does not require management to assign precise values to these weights. Instead they only need to say that they believe output B should receive a greater weight than output A. DEA can be made to take this information into account and then determine a precise numerical values for a new set of weights. The result of this recomputation can again be reviewed by management for the inefficiencies that are then identified. Also identified are new weights for all inputs and outputs. That is, in general, the changes are not confined to weights for products A and B but extend to other products as well. These results provide insights into relations between inputs and outputs that would not otherwise be apparent.

It is to be noted that DEA models provide “best estimates” for each entity being evaluated. The results therefore differ from the “average” of all performances that are used in customary statistical analysis.

Turning to more sophisticated approaches like statistical regression formulations, DEA is much less demanding in its requirements. For example, unlike ordinary statistical regressions, DEA does not require a user to stipulate the form of the relations (linear, nonlinear, etc.) that are supposed to relate inputs to outputs, etc. DEA has therefore lent itself to uses in many applications that have resisted attempts to evaluate performances by other approaches. Examples include evaluating performances of air force units or court and police performances.

In this book, these DEA properties are exploited and explained in terms of commonly used computer codes instead of the underlying mathematical models. Numerical examples and actual applications accompany the expositions. Results and managerial reactions are described that cover a variety of service industry applications.

One such example applies DEA to the numerous branches of a large U.S. bank in an application that resulted in substantial savings along with output increases and input decreases. Emphasized in this (and in other applications) is the use of quality measures, such as customer satisfactions, that play large and important roles in the service industries.

Evaluating hospitals is another example provided in this text because quality there plays a critical role. In fact, quality is a multi-dimensional and complex concept that required careful attention in the example application that is described in terms of a Health Maintenance Organization that utilizes panels of physicians ranging from general practitioners to specialists in many different specialties.

Turning to government services, an example is supplied which is based on work done with the Canadian Department of Supply and Services which, like the U.S. General Services Administration, serves as a procurer of supplies and services for the Canadian government. Here it was necessary to incorporate political considerations and to deal with initial skepticism (and even hostility in some quarters) en route to successful outcomes that are described in this book.

An emphasis on quality also appears in yet another unusual application in which DEA is used to evaluate the “quality of life” in American cities with results that compare favorably with Fortune magazine rankings (and provide added insight) based on the data obtained from the magazine’s survey.

Finally, a use of DEA to evaluate “hedge fund” performances is described in order to illustrate how elements of “risk” as well as “return” can be incorporated in DEA analyses. Here the managerial use extends to “funds of hedge funds,” which is to say that several hedge funds under a common fund are evaluated so that shortcomings in each of their performances may be easily identified for managerial attention.

There is, of course, much more that can be done in dealing with the service industries that now constitute nearly 80% of U.S. economic activity. This book provides a good (user friendly) start that will undoubtedly lead to further applications. Still further prospects also come into view. For instance, this last chapter (on hedge funds) provides a start toward uses of DEA in the knowledge-based-information economy toward which the U.S. is now transiting.¹

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¹ For a good description of the transformation of the U.S. economy from manufacturing to service and now to a information based economy see Kozmetsky and Yue (2005).

Preface

How do you manage profitability of a network of hundreds or thousands of bank branches disbursed over several states and countries? How can a managed care organization manage the quality and costs of the thousands of physicians providing health services to millions of plan members? What methods would enable a government to ensure that the multiple offices serving citizens across a country are operating at low cost while meeting the required service quality? In each of these three service settings, many service providers deliver a complex set of services to a diverse set of customers. Managers of these organizations seeking excellence use benchmarking to identify and adopt best practices. Reapplying benchmarking in service organizations results in continuous improvement by allowing service units to learn from methods that have proven effective in other service units. This book presents a map of alternate ways to improve service productivity, quality, and profitability, and provides an in-depth guide to using the most powerful available benchmarking techniques to improve service organization performance--Data Envelopment Analysis (DEA).

Data Envelopment Analysis (DEA) is a proven technique to help managers improve service performance. DEA first appeared as a research tool in 1978 (Charnes, Cooper and Rhodes) and was used to evaluate educational programs for disadvantaged students in a series of large scale studies undertaken in U.S. public schools with support from the Federal government. Attention was centered on Program Follow Through—a huge attempt by the U.S. Office (now Department) of Education to apply principles from the statistical design of experiments to a set of matched schools in a nation-wide

study (Charnes, Cooper and Rhodes, 1981)¹. While DEA was originally designed for evaluating performance of non-profit organizations where market prices are not available, researchers soon realized that other organizations also had operating issues that are not adequately analyzed using financial measures. Banking seemed to be one likely business setting that could be analyzed with DEA. With bank services as the focus, DEA first appeared in management press in the *Sloan Management Review* by Sherman in 1984. Banks around the world such as Bank Boston (now Bank of America) and U.S. BankCorp, as well as brokerage firms and mortgage banks, have realized substantial cost savings from DEA since the early 1990s (O'Keefe, 1994; Iida, 1991; Bank Technology Report, 1992).

An example from the banking industry will illustrate the reason banks and other organizations have found DEA particularly valuable. Imagine that you are responsible for 1500 or more bank branches operating in 10 states in the U.S. Would you be interested in knowing that some branches are using more than twice the resources of other branches while offering the same or lower quality service than the less costly branch? DEA locates the best practice branches that are low-cost and high quality. It then identifies the high cost branches that could reduce operating costs while maintaining or improving quality. It is uniquely able to compare each one of these 1500 branches to every other branch and *simultaneously* considers all the types of resources used and all the types of transactions and services provided by each branch. Frequently the result is that there are many branches that are using substantially more resources than other branches providing a similar volume and mix of services, which was not apparent to management using other sophisticated analytic techniques. If the inefficient branches identified with DEA are aligned to approach the best practice branches identified with DEA, the bank can reduce operating costs enough to visibly increase earning per share; moreover, these savings would be annual rather than one-time benefits. Specific changes in the way services are offered, the layout of the branch and the way jobs are defined are identified through this methodology. DEA detects savings opportunities that will endure because they result from installing best practice methods derived from the best service providers in the network. This is in striking contrast to what is experienced in some organizations that achieve dysfunctional savings from across-the-board layoffs and expense cuts.

¹ For a brief background and history of DEA, please refer to chapter 1 in W.W. Cooper, L.M. Seiford and J. Zhu (2004), *Handbook on Data Envelopment Analysis*, Kluwer Academic Publishers, Boston

In the above branch network, DEA identified specific excess resources in specified branches totaling over \$100 million per year. Removing these resources results in real enduring savings and aligning branches with best practice branches, in contrast to cutbacks that stress the operations of the organization and which are often reversed after the crisis that spurred the across-the-board cuts subsidies.

As the manager of this branch network, what would your reaction be to new information that many branches are substantially overusing resources and could operate at much lower cost without sacrificing quality and quantity of services?

- You could say you do not believe it, as you are already using some of the most sophisticated branch management techniques.
- You could try to deny it because it could raise questions about why you did not locate these excess costs earlier.
- You could conclude that it is plausible but that you will not implement these changes because your personal rewards for achieving substantial cost savings are inconsequential.
- Alternatively, you could consider the strengths and weaknesses of your current management systems and consider how this analysis complements your techniques. If it captures dimensions missing in existing analyses, which is usually the case, it will offer new opportunities to reduce costs and improve profitability.
- You also could look at examples of sets of best practice and inefficient branches identified with DEA and examine the validity of that conclusion. When managers with no knowledge of how DEA works have compared branches in this way, even where inefficient branches were reported to be using more than twice their required resources, they have found the results to be compelling, as well as, surprising.

Generally, the conclusion is that the identified weak branches *are* using excess resources, that this excess has gone unnoticed by analytic techniques in use, and that guided by DEA there are ways to improve many of the weak branches to generate substantial and enduring cost savings. All of the above responses have been encountered in applications of DEA and several of these are detailed in this book.

For several reasons, banks with large branch networks and even those with fewer than 50 branches are not able to identify the low cost branches and continue to incur waste and diminished earnings. This is the type of question that confronts Bank of America as it acquired

Fleet Boston, Royal Bank of Canada as it acquires U.S. branches, and virtually any bank with a branch network spread over many states and countries.

How can management be unaware that some branches are incurring excess operating costs compared to their own branches? First, the branches may be geographically far apart—as much as 3000 miles—and bank analytic systems (and politics) do not encourage and sometimes do not even allow such comparisons. While benchmarking with less powerful methods than DEA does occur, generally only branches in the same regions or district, or with the same manager are compared. Second, the techniques most widely used provide a sense that the branches are already well run, because 1) techniques to identify best practices cannot consider and analyze the complex set of branch transactions, and/or 2) the techniques only identify average, not the best practices.

Existing techniques such as queuing models and staffing models do not consider the complex mix of services and resources used by a bank branch and are unable to address the more complex services such as accepting loan applications and opening new accounts. Existing techniques also fail to consider the full range of services provided by the bank branch or other service unit, resulting in a splintered measure of operations and overlooking the synergies of balancing the mix of services and responsibilities assigned to service providers. These methods have been used for years and those using them have forgotten or never knew about the assumptions and weaknesses of these techniques that result in no adjustment to compensate for these weaknesses. If the individuals that evaluate and manage service costs and quality were asked what are the assumptions behind the models and methods used, it is likely that when key assumptions are identified and reconsidered, it may be surprising to realize the nature of the assumptions and how they result in sub-optimal operations. For example, widely used queuing models make assumptions about wait time and about the time it takes for each transaction. They assume each transaction is independent, which is rarely true for the majority of bank transactions.

DEA has generated substantial cost savings and productivity improvements beyond those achieved with other management techniques in diverse service organizations. Many banks have achieved costs savings with DEA while maintaining and improving service quality. DEA has identified new ways to manage health services to provide care at lower cost while maintaining quality. DEA has reduced the cost of government services in the government of

Canada. In one case, the realized benefits were so substantial that one manager described it as “benchmarking on steroids!” Users have acknowledged the benefits of DEA in news articles, journals, and professional publications. Early users had to employ internal or external experts familiar with DEA and its underlying mathematics—linear programming. The need for this type of expertise has been eliminated and the field is open for service managers seeking new insights about ways to improve their operations and competitive advantage via unique analytic capabilities of DEA. This book provides the roadmap for managers to understand DEA, evaluate its value to an organization, and apply and analyze the results to identify specific ways to improve performance and profitability.

Often new methods of managing services are identified via DEA. For example, some banks hold the view that retirement community branches and small branches are naturally less efficient—retirees like to chat with service providers and small branches have minimum staffing levels that burden their operations. DEA has been used to develop best practice small branch models that are as or more efficient than large branches. Other applications have demonstrated that there are best practice retirement community branches that can serve as models for other similar branches and they can be as productive as the large urban branches. In fact, many large urban branches have been identified with DEA as under-performing, but they were previously never challenged to improve performance because existing financial performance measures erroneously report them as best practice branches.

Similar issues confront other services environments. Both discount and retail brokerage firms have separately compared their office activities and wondered how it could identify the best practice office systems. The government of Canada has multiple offices providing similar services across Canada. Responding to the clamor for streamlining government costs of operations, they applied DEA to identify ways to provide the same service level and reduce operating costs where there is excess compared to best practice offices. In health-care, new insights about managing hospital costs, nursing home costs, and physician practice pattern costs have emerged from this technique.

This book guides managers and other readers in the use of DEA as a benchmarking technique to 1) identify high cost service units, 2) identify specific changes to each service unit to elevate their performance to the best practice services level providing high quality service at low cost, and 3) guide the improvement process. Every

assertion and method described herein is supported by an application to an organization that sought to improve performance. Areas where DEA is beneficial and where it can provide only limited benefits are discussed in the context of results and managements' reaction to the DEA findings.

Most of the benefits of DEA have been discussed only in technical academic journals. Recently, this technique has become accessible to any and all managers with access to Microsoft® Excel spreadsheet software (Excel). This volume includes step-by-step guidance to enable readers to apply DEA with Excel to their organization. This book also provides ready-to-use DEA software for Microsoft® Excel Add-In to run DEA analyses on any set of organizations of interest to the reader.)

We provide an overview of the chapter contents to help readers already familiar with aspects of DEA to focus on those chapters that may offer valuable added insights.

Chapter 1 provides an overview of key existing management techniques for improving service organization performance. This suggests the landscape of methods against which a manager can evaluate the value of using DEA. Situations in which DEA would be superfluous and less insightful than other methods are identified along with examples of DEA offers superior insights but where yet other tools need to be developed.

Chapters 2 through 5 offers managers with the DEA foundation information on how to apply DEA, and how to interpret DEA results to benefit a service organization. Chapter 2 explains the basic logic behind DEA and where it is most powerful and where it is limited via simple examples of different ways to measure productivity. This chapter is ideal for those first learning about DEA. While the simple examples given may seem a little tedious and elementary, misunderstanding of basic concepts has resulted in misapplication of DEA and erroneous conclusions about ways to improve service performance. Consequently, we encourage even those managers with some background in DEA to review this chapter.

Chapter 3 offers a clear explanation of how DEA works, the computations that generate results, and the concepts that drive productivity analysis. This provides the foundation for the reader to understand appropriate ways to apply and benefit from DEA. Examples used here build in complexity, but they maintain a level where one can visualize the solution provided by DEA to allow one to anticipate its value with a full complex data-base where one could not

otherwise locate the productivity improvement paths identified with DEA.

Chapter 4 introduces *DEA Frontier* software contained with this book and provides a step-by-step guidance on using this software with Microsoft® Excel to generate the solutions to the problems already analyzed in the previous chapters. This will enable a manager to run the DEA analysis to gain confidence in the software, the layout of the data and the solutions, and the interpretation of the DEA solution. This can then be adapted to any application and related data available to the reader.

Chapter 5 describes several of the many extensions to DEA. We discuss selected DEA approaches that are likely to be useful to managers, such as a returns to scale DEA model and a model that increases the power of the analysis by constraining some of elements in the analysis via input of management preferences, expertise, or other knowledge about the variables. Another particularly important DEA extension is described in depth in Chapter 7a method for including service quality in the analysis. This is an example of DEA adapting to the recognition that service quality is a critical element in measuring and managing service organizations.

Chapters 6 through 9 give detailed case studies of applications of DEA, indicating the problem being analyzed, the way DEA is applied, management's response to the analysis and the impact of the analysis. The applications include banking (Chapter 6), quality adjusted DEA (Q-DEA) applied to a bank (Chapter 7), physician practice pattern analysis (Chapter 8), and government services (Chapter 9). Three of these studies generated real documented benefits to the organization and one includes explicit management feedback on the benefits.

Chapters 10 and 11 describe new DEA uses that are in early stages of development, which have the potential to create new highly attractive options to analyze quality and to evaluate risk-reward tradeoffs in organizations. Chapter 10 describes an analysis of the quality of life in major cities using Fortune Magazine data. The concepts and value of DEA are illustrated and may form the basis for new breakthroughs in analyzing and managing service quality beyond the level suggested in Chapter 7. Chapter 11 describes assessments of hedge funds to identify those providing the greatest return for a given downside risk level. While the value of hedges fund performance measurement is substantial for investors and fund managers, the broader concept of measuring the balance of risk and reward with DEA may prove valuable to other industries that are challenged with the need to balanced risk and reward.

The authors are grateful for the comments and suggestions made by Dr. Greg N. Gregoriou on chapter 11. The authors also wish to thank Dr. W.W. Cooper for his numerous comments and suggestions on an earlier version of the book. However, any errors in the book are entirely our responsibility, and we would be grateful if anyone would bring any such errors to our attention. You are also invited to email or call with questions about the content of the book and methods of applying DEA. We would be interested in hearing about successful and problematic applications you encounter. Our objective to develop a book that would help users apply DEA and any suggestions and corrections are very welcome. Our email addresses are: h.shermand@neu.edu and jzhu@wpi.edu.

David Sherman and Joe Zhu, February 2006.