

INTRODUCTION

1.1 OBJECTIVE OF THE RESEARCH

The purpose of this research effort is to measure and evaluate efficiency and effectiveness and maintain operational viability in a fuzzy environment using features of data envelopment analysis (DEA), goal programming (GP) and fuzzy set theory. This can be expressed by the following three objectives. The first objective is to propose a simple framework to measure and evaluate efficiency, effectiveness and operational viability in a fuzzy environment using features of data envelopment analysis (DEA), goal programming (GP) and fuzzy set theory that assumes deterministic inputs and outputs, imprecise goal aspiration levels and different decision-making scenarios. The concept of operational viability is introduced to capture the need to maintain minimal operating levels for certain inputs and/or outputs for viable operating conditions given *a priori* historical knowledge about the system. The second objective is to test the proposed model with an application to a newspaper preprint insertion process of a leading newspaper manufacturer using real data. The third objective is to outline the decision-making information made available from the proposed framework that can be used for the evaluation of technical or input/output efficiency performance, achievement of global input/output targets and future resource allocation strategies.

An application to a packaging line of a leading newspaper manufacturer forms the applied component of this research. The data for this application is adopted from Girod (1996). The process of concern is a newspaper preprint insertion process that involves multiple inputs and an output. The methodology proposed in this research is applied to the data for the packaging line to measure and evaluate efficiency and effectiveness under different scenarios in a fuzzy environment.

1.2 MOTIVATION

Measurement and evaluation of efficiency has been an ongoing research issue in management science. Further, there has been a growing interest in using information from efficiency research for intelligent decision-making regarding achievement of organizational goals and resource allocation strategies. The mathematical programming approach for efficiency measurement has been one of the important techniques used for efficiency measurement. However, the mathematical programming technique requires deterministic data and crisp model constraints. That is the data is required to be available in precise terms and the constraints of the model are required to be satisfied *precisely*. However, in reality, these conditions are not always met. Often data are imprecise or subject to incomplete knowledge. A violation of the constraint by any degree is assumed to be unacceptable.

Sengupta (1992) applied principles of fuzzy set theory developed by Bellman and Zadeh (1970) and Zimmermann (1976) to data envelopment analysis. Sengupta (1992) introduced fuzziness in the objective function and the right-hand side vector of the conventional DEA model developed by Charnes, Cooper and Rhodes (1978). However, Sengupta (1992) did not provide an application roadmap of his proposed framework to measure efficiency using fuzzy DEA. Girod (1996) and Parlikar (1996) developed fuzzy radial and non-radial models respectively for efficiency measurement in a fuzzy environment using imprecise data and precise (crisp) constraints. That is, Girod (1996) and Parlikar (1996) addressed the issue of vagueness in the data in their research while maintaining crisp relationships for the inputs and outputs. In these research efforts the decision-maker has incomplete knowledge about the data and thus has imprecise data. However, the aspiration levels (constraints) and tolerance levels (acceptable violation of the constraints) are not of concern, and thus, are precise.

In reality, when a decision-maker is faced with multiple goals the optimal achievement of all goals is rarely possible. More often than not the decision-maker is

looking for *satisficing* levels of goal achievement within some predefined acceptable limits rather than an optimal solution. Crisp mathematical programming approaches are limited in such cases as they provide only crisp representation of systems. Further, the decision-maker may want to assign relative importance to the achievement of the goals but may be reluctant to assign quantitative preferences between goals. Also, the decision-maker may, in certain scenarios, desire crisp achievement of some goals while allowing imprecise achievement of other goals. The need to model such scenarios provides the fundamental motivation for this research.

The decision-maker can be faced with several problems of interest in the context of meeting efficiency and effectiveness goals. The first problem is to measure and evaluate efficiency in terms of its input consumption and output generation. The efficiency measurement exercise should provide decision-makers with information useful for improving resource usage. The second problem is to relate operational level efficiency to global organizational targets or effectiveness. The third problem is to provide higher level decision-makers with a decision-making tool to evaluate current efficiency performance at the process level as well as the organization as a whole and make decisions regarding efficiency improvement for resource usage, future resource allocation strategies and achievement of global targets. The framework developed in this research can be used to address these issues.

1.3 OVERVIEW OF THE RESEARCH METHODOLOGY

This research presents a framework to measure and evaluate efficiency and effectiveness in a fuzzy environment. The proposed framework uses DEA and goal programming in conjunction with fuzzy set theory. The mathematical model thus developed is called the Fuzzy GoDEA model and is based on Athanassopoulos' (1996) goal programming and DEA (GoDEA) model.

The Fuzzy GoDEA framework assumes that the decision-maker has knowledge about crisp input and output data but imprecise aspiration levels for the goals of efficiency and effectiveness. Further, the Fuzzy GoDEA Base Model is extended into several variations that allow the decision-maker to subjectively assign importance to the goals of efficiency and effectiveness and also permits the scenarios where either one of the efficiency or effectiveness goal is crisp and the other fuzzy. In all these cases, the Fuzzy GoDEA framework provides the decision-maker with a decision-making tool to analyze and improve efficiency and effectiveness performance.

The fuzzy dimension of this research associates membership functions with the fuzzy goals (or constraints) which denote the degree of satisfaction of these goals. The efficiency goal is modeled using DEA techniques while the effectiveness goal is modeled using Athanassopoulos' (1995) GoDEA approach with slight modifications. The fuzzy concepts used in this research are adopted from Zadeh 's (1965) classical fuzzy set theory and Zimmermann's (1976) work in fuzzy systems. Finally, Sengupta's (1992) and Girod's (1996) research in fuzzy DEA and classical fuzzy goal programming provide the theoretical concepts to complete the formulation of the Fuzzy GoDEA model.

The Fuzzy GoDEA model is implemented with real-life data from a newspaper preprint insertion packaging line. The model specification and the data are derived from Girod (1996) and are chosen due to the availability of prior fuzzy efficiency results (Girod (1996), Parlikar (1996)) and operational information regarding the data. The data span forty-eight observations where each observation represents a production week. Each observation is called a production day as the packaging line undertakes production once a week. The Fuzzy GoDEA model and its variations are applied to the packaging line data to obtain results pertaining to the achievement of the efficiency and effectiveness goals. The operational viability concept developed for the Fuzzy GoDEA framework is omitted from the application due to non-availability of suitable data. These results are analyzed for insights regarding the operating characteristics of the packaging line. Further, the results are examined for additional information that verifies the consistency of the fuzzy efficiency results as compared with the conventional DEA

efficiency results. Also, analysis of the behavior of the Fuzzy GoDEA framework in achieving the simultaneous goals of efficiency and effectiveness is described. This is followed by an evaluation of the performance of the packaging line. Finally, the research is concluded with recommendations for future research.

1.4 ORGANIZATION OF THE DOCUMENT

This chapter introduced the research undertaken in this thesis. The remainder of the document is organized as follows. Chapter 2 comprises a literature review that summarizes research in the area of efficiency measurement, data envelopment analysis, multi-level programming, goal programming, fuzzy set theory, fuzzy goal programming, and fuzzy data envelopment analysis. Chapter 3 describes the proposed Fuzzy GoDEA framework that is developed in this research. Chapter 4 provides a detailed description of the newspaper preprint insertion process and construction of the data for the application of the Fuzzy GoDEA model. Chapter 5 details the results obtained for the packaging line application, presents analysis of the results for the different Fuzzy GoDEA model variations, and evaluates the performance of the packaging line. Finally, Chapter 6 concludes this thesis presentation with a summary of the research contribution and recommendations for future research.