Graduate School of Creative Science and Engineering
Waseda University

博　士　論　文　概　要
Doctoral Dissertation Synopsis

論　文　題　目
Dissertation Title

The Least-Distance Data Envelopment Analysis Based Efficiency Evaluation and Benchmarking

最短距離データ包絡分析法に基づく効率性評価やベンチマーキング

申　請　者
(Applicant Name)
Xu WANG
王　緒

Department of Industrial and Management Systems Engineering
Research on Mathematical Decision Making

November, 2021

Data envelopment analysis (DEA) has been widely applied to evaluate the relative efficiency and provide the benchmarking information (efficient target) for decision making units (DMUs) since introduced in 1987. DMUs may include such as banks, hospitals, and schools. In DEA, two frameworks are commonly used for efficiency evaluation and target setting, including: the greatest- and least-distance frameworks, which provide the farthest and closest efficient targets for the DMU under evaluation, respectively. Studies on the former includes the conventional Charnes Cooper and Rhodes (CCR) model, Banker Charnes and Cooper (BCC) model, additive (ADD) model, range adjusted measure (RAM), and slacks-based measure (SBM). However, the closest efficient target (CET) is often more appropriate than the farthest efficient target, which was first noted in 1999 and has since become widely believed among many DEA researchers. Because the CET is always more easy-to-achieve and acceptable form the perspective of the managers of DMUs. Thus, DEA researchers tend to aim to minimize the distance between the DMU under evaluation and the efficient frontier to obtain an easy-to-achieve efficient target, which indicates the CET. Inspired by that, this thesis focuses on both the theoretical and practical aspects of efficiency evaluation and benchmarking based on the least-distance DEA.

The least-distance DEA has been extensively researched because of the practicability of the least-distance benchmarking information, which indicates the CET, since proposed in 1999. However, no approaches have been developed that can compute the CET over the entire efficient frontier. The computation of the CET is considered to be difficult because the current definition of the efficient frontier is implicit. In addition to the computation issue, the least-distance DEA model encounters problem on the satisfaction of a set of desirable properties accepted in DEA, especially monotonicity. Thus, the development of a well-defined least-distance DEA model that satisfies these desirable properties is necessary. The aforementioned aspects are the motivations for this thesis. In this thesis, I focus on the computation of the CET and the proposal of a new least-distance DEA model satisfying the desirable properties in DEA. Concretely, a new MIP approach, which is referred to as the NMIP approach, is proposed for the computation of the CET. Besides, a well-defined least-distance range adjusted measure is proposed as a model for efficiency evaluation and benchmarking, which is referred to as LRAM. And the main contents of the thesis are briefly summarized as follows.

Chapter 1 offers the background of this research, reviews the related

previous works, addresses the objectives, and shows the structure of this thesis.

Chapter 2 provides the basic concepts of DEA on efficiency evaluation and benchmarking. It begins by introducing the definition of the production possibility set. Four notable properties of the production possibility set and two commonly used production possibility sets are illustrated in detail. The efficiency of DMUs is the most concerned in DEA. Hence, the attention then moves to the efficient frontier, including the definition of the efficient frontier, the illustration of the two kinds of the efficient frontier, and remarks on the current definition of the efficient frontier. Finally, I introduce the famous CCR model and BCC model, and a simple numerical example is given to show how a DEA model works.

Chapter 3 concerns on the theoretical background of the least-distance DEA. I illustrate the least-distance DEA at first and emphasize its difference from the conventional DEA. From the illustration and comparison, the necessity of the least-distance DEA is more rigorously established. Subsequently, I introduce four desirable properties in DEA and three representative least-distance DEA models, including their formulations and features. Finally, the issues in the least-distance DEA, such as the computation and property of the models, are discussed.

In Chapter 4, I focus on the computation of the CET in DEA. First, the Karush-Kuhn-Tucker (KKT) condition is used to redefine the efficient frontier to be computation-friendly. Using this definition, I find that the CET can be obtained by solving a mathematical program with linear complementarity constraints. Therefore, a new MIP approach, which is referred to as the NMIP approach, is proposed for the computation of the CET in this chapter. The difference between the NMIP approach and the representative previous MIP approach is thoroughly analysed and discussed. Moreover, numerical experiments are conducted to compare the performance of the NMIP approach with that of the previous MIP approach. I further discuss possible extensions and applications of the NMIP approach at the end of this chapter.

In Chapter 5, I develop a well-defined least-distance range adjusted measure as a model for efficiency evaluation and benchmarking, which is referred to as LRAM. The conventional range adjusted measure (RAM), which acts as a well-defined model satisfying a set of desirable properties, is introduced first for comparison. Thereafter, building upon the work of the existing studies, the LRAM is developed. Relying on the NMIP approach in

Chapter 4, I show that the LRAM can be computed easily. Details on the LRAM, including the description and computation approach of the measure, are provided in this chapter.

Chapter 6 investigates the performance of the LRAM by applying it to a sample, which contains the data of Japanese banks corresponding to the period 2017-2019. As a preliminary preparation, data description and input/output variable selection are initially performed. The analysis is divided into two parts, including performance and benchmark analysis. For the benchmark analysis, I quantify the extent of input-output modification to enable a direct comparison between efficient targets yielded by the RAM and LRAM. In fact, these modification percentages are presumed to be necessary for inefficient banks to achieve efficiency, and they have consistently been implemented in DEA.

Chapter 7 concludes the thesis and suggests some possible directions for future research.

List of research achievements for application of Doctor of Engineering, Waseda University

Full Name : 王　緒　　seal or signature

Date Submitted(yyyy/mm/dd): 2022/2/4

種類別 (By Type)	題名、 発表・発行掲載誌名、 発表・発行年月、 連名者（申請者含む） (theme, journal name, date & year of publication, name of authors inc. yourself)
Academic papers	(Refereed journal papers)
○	[1] Xu Wang, Takashi Hasuike, Least-Distance Range Adjusted Measure in DEA: Efficiency Evaluation and Benchmarking for Japanese Banks, Asia-Pacific Journal of Operational Research. (accepted)
○	[2] Xu Wang, Kuan Lu, Takashi Hasuike, A New Approach on the Lowest Cost Problem in Data Envelopment Analysis, Asian Journal of Management Science and Applications, 2021, 6(01):69-84.
○	[3] Xu Wang, Kuan Lu, Jianming Shi, Takashi Hasuike, A New MIP Approach on the Least Distance Problem in DEA, Asia-Pacific Journal of Operational Research, 2020, 37(06):1-18.
	(Refereed international conference papers)
	[1] Xu Wang, Takashi Hasuike, The Least-distance DEA Based Efficiency Improvement Under Multiple Perspectives, Proceedings of 2021 IEEE International Conference on Industrial Engineering and Engineering Management(IEEM 2021), pp.818-823.
○	[2] Xu Wang, Takashi Hasuike, Least-distance Data Envelopment Analysis Model for Bankruptcy-based Performance Assessment, Proceedings of 2020 IEEE International Conference on Industrial Engineering and Engineering Management(IEEM 2020), pp.235-239.
Reviews (not refereed)	[1] Xu Wang, The Least Distance Problem in Data Envelopment Analysis: the proposal of a new MIP computation approach, Communications of Japan Industrial Management Association, 2020, 30(1): 73-78.(in Japanese)
Lecturers	(International conference)
	[1] Xu Wang, Takashi Hasuike, The Least-distance DEA Based Efficiency Improvement Under Multiple Perspectives, 2021 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM2021), Online, December 13-16, 2021.
	[2] Xu Wang, Takashi Hasuike, Least-distance Data Envelopment Analysis Model for Bankruptcy-based Performance Assessment, 2020 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM2020), Online, December 14-17, 2020.
	[3] Xu Wang, Takashi Hasuike, DEA Based Bankruptcy Assessment Approach, 2019 INFORMS Annual Meeting, Seattle, America, October 20-23, 2019.
	[4] Xu Wang, Takashi Hasuike, Cost Minimizing Target Setting Over the Whole Efficient Frontier in Data Envelopment Analysis, 2019 Asian Conference of Management Science and Applications (ACMSA2019), Penglai, China, October 11-14, 2019.
	[5] Xu Wang, Takashi Hasuike, Jianming Shi, Kuan Lu, The Least Distance Problem in Data Envelopment Analysis, The 13th International Symposium on Operations Research and its Applications(ISORA 2018), Guiyang, China, August 22-26, 2018.
	(Internal conference)
	[1] Xu Wang, Takashi Hasuike, Least-Distance Range Adjusted Measure for Efficiency Evaluation and Benchmarking in DEA, 2021 Spring Forum of the Operations Research Society of Japan, Online, March 2-3, 2021.
	[2] Xu Wang, Takashi Hasuike, Cost Minimizing Target Setting Based on the Least Distance Model in DEA, 2020 Spring Forum of the Japan Industrial Management Association, Akita, March 5-6, 2020.

List of research achievements for application of Doctor of Engineering, Waseda University

Full Name： 王　緒　　seal or signature

Date Submitted(yyyy/mm/dd): 2022/2/4

種類別 (By Type)	題名、 発表・発行掲載誌名、　　発表・発行年月、　　連名者（申請者含む） (theme, journal name, date & year of publication, name of authors inc. yourself)
	[3] Xu Wang, Takashi Hasuike, Data Envelopment Analysis Based Financial Performance Evaluation and Bankruptcy Assessment，2019 Spring Forum of the Japan Industrial Management Association, Fukuoka, March 7-8, 2019. [4] Xu Wang, A Branch and Bound Approach for the Least Distance Problem in DEA，[Workshop: Evaluation OR] of the Operations Research Society of Japan, Student Meeting, Tokyo, May 19, 2018. [5] Xu Wang, Kuan Lu, Jianming Shi, A Method of Computing the Closest Efficient Projection Point in Data Envelopment Analysis，2018 Spring Forum of the Operations Research Society of Japan, Tokyo, March 11-14, 2018. [6] Xu Wang, A Method of Calculating Closest Efficient Projection in Data Envelopment Analysis， [Tohoku OR Seminar: Young Research Exchange Meeting] of the Operations Research Society of Japan, Yamagata, November 25-26, 2017.