Increasing the Performance Efficiency of Bread Bakery Company Using Data Envelopment Analysis (DEA)

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ABSTRACT

The market competition of bakeries in recent years have undergone rapid and massive growth, because of this fast growth and change, this necessitate the need for comprehending the performance relative efficiency as well as efficiency fluctuation and changes of the bakeries. Nowadays, food industries and bakery companies tends to use their current available production resources in an inefficient manner, as such, managing and sustaining the development of the bakery regarding how well it is performing when it comes to the production process is very important. Thus, ten inputs and two outputs of a bakery company were considered as the DMUs. The efficiency of inputs such as flour, salt, sugar, butter, yeast, water, electricity consumption, etc., and outputs (bread and flour waste), involved in the production process of a well-known bakery (Tahir B-bakery) from 2016 to 2018 was quantitatively analyzed and evaluated by adopting one of the most well-known, simple and suitable non- parametric effective technique (DEA) via using the CCR input oriented model. Based on the model used, the overall efficiency of the company in those past three years of Tahir B-bakery with regards to the use of input resources for achieving output was tested, it was found the company's performance is relatively efficient with an average efficiency score of 92.6. The most efficient months being June and July in both 2016 and 2017 respectively, although there is a slightly decrease of efficiency as the years gone by, especially in the month of June and July in 2018 plus the fact that the aim of any firm is to reach maximum level of efficiency when it comes to utilizing the inputs and outputs production resources, as well as other resources involved. Lastly, given the fact that there is a tendency the performance efficiency to drop more as the year's progress, they can follow the recommended ways for improving their total efficiency, sustain it and avoid further decrease of efficiency for their future productions to come.

Keywords: Bakery Company; Data Envelope Analysis (DEA); CCR Input Oriented Model

ÖZ

Fırınların son yıllarda pazardaki rekabeti hızlı ve büyük bir büyüme yaşamıştır, bu hızlı büyüme ve değişim nedeniyle, bu, performansın göreli verimliliğinin yanı sıra verimlilik dalgalanmasının ve fırınların değişimlerinin anlaşılması gereğini gerektirmektedir. Günümüzde, gıda endüstrileri ve fırın şirketleri mevcut mevcut üretim kaynaklarını verimsiz bir şekilde kullanma eğilimindedir, bu nedenle fırının üretim süreci söz konusu olduğunda ne kadar iyi performans gösterdiğine ilişkin gelişimini yönetmek ve sürdürmek çok önemlidir. Böylece, bir fırın şirketinin on girişi ve iki çıkışı DMU olarak kabul edildi. Un, tuz, şeker, tereyağı, maya, su, elektrik tüketimi, vb. Gibi girdilerin ve iyi bilinen bir fırının (Tahir B-fırın) üretim sürecinde yer alan çıktıların (ekmek ve un atığı) verimliliği 2016'dan 2018'e kadar, CCR girdi odaklı model kullanılarak en iyi bilinen, basit ve uygun parametrik olmayan etkili tekniklerden (DEA) biri kullanılarak nicel olarak analiz edilmiş ve değerlendirilmiştir. Kullanılan modele dayanarak, Tahir B-fırınının son üç yılda çıktı elde etmek için girdi kaynaklarının kullanımına ilişkin genel etkinliği test edilmiş, şirketin performansının ortalama verimlilik puanı ile nispeten verimli olduğu bulunmuştur. 92.6. En verimli aylar hem 2016 hem de 2017'de sırasıyla Haziran ve Temmuz'dur, ancak yıllar geçtikçe verimlilikte hafif bir azalma olmasına rağmen, özellikle 2018'de Haziran ve Temmuz aylarında artı herhangi bir firmanın amacının üretim kaynakları ile ilgili diğer kaynakların yanı sıra girdi ve çıktıların kullanımında da maksimum verimlilik seviyesine ulaşır. Son olarak, performans verimliliğinin yıl ilerledikçe daha fazla düşme eğilimi olduğu gerçeği göz önüne alındığında, toplam verimliliklerini artırmak, bunu sürdürmek ve gelecekteki üretimlerinin gelecekteki verimliliğini daha da azaltmak için önerilen yolları izleyebilirler.

Anahtar Kelimeler: Fırın Şirketi; Veri Zarfı Analizi (DEA); CCR Giriş Odaklı Model.

To my Family and Late Father (Alhaji Aliyu Madakin Bade)

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LIST OF ABBREVIATIONS

DEA	Data Envelopment Analysis
DMU	Decision Making Unit
FPI	Food Processing Industries
Kg	Kilograms
Kwh	Kilowatts
L	Liters
LP	Linear Programming
PIM-DEA	Performance Improvement Management Software

Chapter 1

INTRODUCTION

Food is considered as one of the most basic needs in human life, with rapid and massive increase in population, its necessary to focus and take the food sector more important than any other economic sector, food contributes a lot to the development and growth of any countries economy, as such, it is a key indicator of development and growth as well as quality of life of the people at any national level.

1.1 Preamble

Change and competition has always been the main characteristics of many industrial organization, as a result of the intense competition and subsequent change that exists between industrial organizations or any production company, organizations can only achieve their goals and objectives in an effective and efficient manner only if they are able to allocate their available resources effectively in such a complex and dynamic conditions.

Tahir Bakery and confectioneries was established in the year 2007 17^{th} of September, the name Tahir bears the name of the company's owner grandfather who passed away 60 years ago. The name today serves as a symbol of the family name as well as various product name such as Tahir bread, Tahir table water, Tahir Islamic academy, Tahir Clinic etc. Tahir bread bakery is located at 6/7 Nnamdi Azekwe expressway by-pass bakin ruwa Kaduna Nigeria. It is one of the most growing and popular bakeries that helps contribute to the economy of Kaduna state and Nigeria as a whole. The company comprises of different production sectors which includes bread, cakes, pastries and other baking product. As a result of intense growth in population and high demand for food production, its necessary for the company to continue producing food products in a way that benefits and suits both the company, their consumers as well as the Government itself and to also prevail and overcome competitions from various other food production industries, they must be able to identify their vulnerabilities, produce food products in an effective, efficient and productive manner. This can only be done via the evaluation of their resources and measuring the efficiency of their production process by considering various inputs and outputs.

Hence, the aim of this thesis project is to measure the performance of bread production sector of the above mentioned bakery company as well as its efficiency by measuring the performance and evaluating the technical efficiency of the various inputs such as flour, sugar, salt, butter, energy consumption, etc. as well as the outputs such as amount of flour wasted and the final product which is bread so as to identify the benchmark or the determinants of the company's technical efficiency by adopting one of the industrial engineering technique. As such, performance evaluation and determination of opportunities is necessary for any industrial organization for its determination of strength and weakness of the organization.

1.2 Problem Statement

It is a well-known fact that one of the major problems faced by any industry is how to increase their energy efficiency in order to achieve maximum efficiency level in their production also to counter the problem of using their various resources inefficiently. Food production companies have faced so many challenges on how to find the actual bench mark that will increase their production efficiency as well as increase their performance. Therefore the secret to a successful, productive, and efficient production of any product depends on how good the company can evaluate their resources (raw materials) as well as improving the energy productivity. These can only be done by considering and evaluating the daily, monthly or yearly inputs and outputs in any production set up and considering the most efficient period to serve as a bench mark for the rest of the production periods. This will resolve the problem of using resources inefficiently as well as allow the company to be able to withstand competition from its competitors. Therefore, this study was conducted in a bread bakery production company to increase their production efficiency as well as energy efficiency by considering the monthly various resources or raw materials i.e. inputs like flour, sugar, salt, flavor, electricity consumption, improver, etc. and outputs such as flour wasted and bread for three successive years and analyzing and evaluating all these decision making units by using performance improvement technique so as to identify the reasonable critical period in which the company was more efficient, effective and more productive as the period will serve as a bench mark for all future production periods to come [1].

Consequently, more of the energy use causes problems by threatening public health and environment. Some of the benefits of efficient use of resources involved in agriculture and food production industries and bakeries as one of the major principal requirements of sustainable development are;

- reduce the environmental problems drastically, prevents the destruction of natural resources
- promote food production in an efficient manner

- Find suitable measures for achieving the stated goals and aims
- Recommend ways to follow for improving future performance efficiency and company's goals.
- Justify the selection of the technique used in conducting the research.
- Boost the production of agriculture sustainably in an economical manner [2].

Raw materials involved in food production companies and agricultural production and energy usage has been investigated in many studies. Efficiency was described by Sherman [3] as the weights of produced outputs while utilizing the lowest possible weight of input resources. The weights of production frontier or variables (inputs and outputs) are the best measuring unit for maximizing relative efficiency. Hence, production variable specification is important for optimal efficiency computations [3]. Efficient energy usage for production processes in Food Production Industries (FPI), bakeries and agriculture is the key to sustainable energy management; therefore, to improve energy efficiency, high production yield is necessary to conserve energy input while attaining desired output [1]. DEA is a nonorthodox technique of estimating production frontiers used extensively in various FPI sectors for efficiency computation and benchmarking of DMU [4]. Generally the major factor of green and sustainable production in agriculture has identified to be the efficient management of resources [5]. The need to increase food production has resulted to increase in total consumption of energy and natural resources because many food production companies and industries have little knowledge of or few intensives to use more energy efficient methods [6].

1.3 Research Motivation

In many developing countries, there exist the need to constantly increase the country’s economy as well satisfy the need for present and future demand of food products due to the massive rise in population. This can only be done when both parties that is, both the government, consumers and the producers of such food products are able to benefit in such an efficient and effective manner.

Many companies and food production industries have adopted so many techniques and methods for evaluating the technical efficiency of their production process which has led to massive increase in their total production capacity and efficiency as well as massive increase to the country’s economy. DEA is among the most modern and most widely used model which is used by such companies that enabled them to increase their process efficiency, avoided the use of resources inefficiently, increase their countries economy as well solved the problem of high demand of food products due to increase in population in the most effective, productive and efficient manner.

Therefore the need to apply such technique and model which happens to fall in my discipline to improve the above mentioned company’s efficiency, maximize the country’s economy, solve the problem of high demand of food products by evaluating various decision making units of the company and setting important and necessary benchmark for improving the productivity of the company is what motivated the conduction of this research. Also, one of the reason that motivated the research is to get the knowledge of the application of data envelopment analysis (DEA) in so many public, production as well as economic sectors and the importance of such model and the mechanism behind it. Moreover, the study is also aimed at achieving the following objectives at the end of the research;

- ❖ Find suitable measures for achieving the stated goals and aims
- ❖ Recommend ways to follow for improving future performance efficiency and company's goals.
- ❖ Justify the selection of the technique used in conducting the research.

1.4 The Thesis Structure

The thesis will be structured and organized based on the various remaining chapters which are chapter one, two, three, four, and five.

These different thesis chapters will entails the following: starting with the next Chapter to follow which is Chapter Two, this Chapter contain the literature review based on the previous work done by others which is related to increasing energy efficiency and productivity on different industrial food sectors using the technique of the data envelopment analysis (DEA) to give a better understanding on the technique and model used; Chapter Three will discuss the methods followed to identify the inefficient use of energy and production resources and describe possible means of achieving efficiency; Chapter Four will discuss about how the company's data based on various inputs and outputs was collected and analyzed along with different tables and figures which were used to discuss more about the result obtained, and the last but not the least, is Chapter Five; this concludes the thesis research by a brief summary of the results obtain and future work for certain field of study.

In a nut shell, the structure of the thesis is listed as follows and shown in a hierarchical order in Figure 1.1 below.

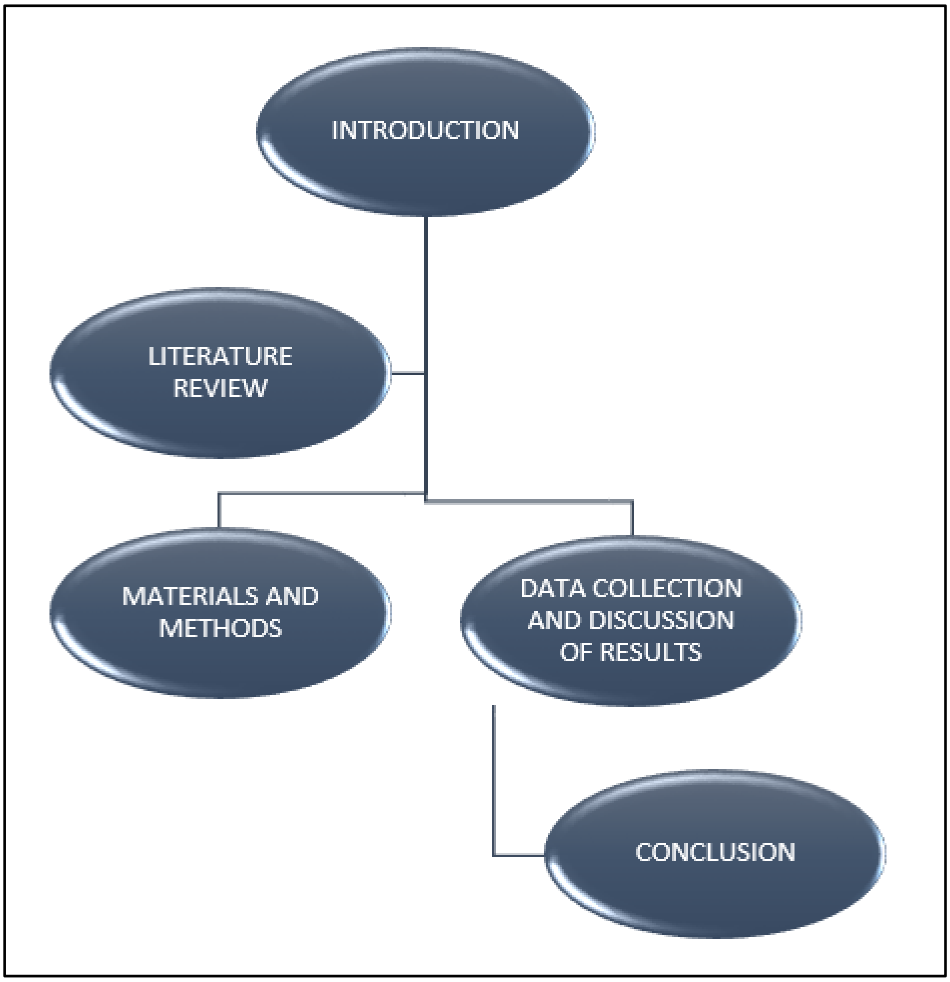

Figure 1.1: Thesis Structure

Chapter 2

LITERATURE REVIEW

There have been so many applications of DEA in many different sectors by so many different authors, however, it is necessary and important to take a review of research and work done by this authors using the DEA technique in such areas to have a better view and understanding of its applications in both companies related to bakeries and other food sectors. The application of DEA will be better understood by reviewing the previous work of some authors, where DEA was applied, areas in which it was applied and how these authors come up with a better solutions for improving the performance of certain areas that will be reviewed. However, the main literature review will be based on the previous work done by others mainly in food sectors and Bakery Company by adopting the DEA technique. In addition, some areas which will help us better understand, analyze the how DEA was applied and also to give us a better understanding regarding this research will be reviewed. In addition, the DEA modified models will also be taken into consideration.

2.1 Preamble Literature Review

The vast applications of DEA is seen as a very important tool for evaluating production frontiers of any industrial or commercial sectors. There exists many parametric techniques of evaluating performance such as regression analysis, but the key to using DEA is it is a non-parametric technique that can improve the performance of a process involving multiple inputs with less output i.e. the input oriented CCR model which is same model used in this study. There are two types of

DEA models which are the CCR and BCC model, CCR model was introduced or established by Charnes et al (1978), while BCC was introduced by Banker et al (1984) through the modification of the CCR model, BBC model can be seen as the improved and integrated model of the CCR. This BCC model can evaluate the technical as well as the pure technical efficiency of any production frontiers. Moreover, there are also DEA models which address varying returns to scale, either CRS (constant returns to scale, VRS (variable), non-increasing returns to scale or the non-decreasing returns to scale by Ylvinger (2000). The main developments of DEA in the 1970s and 1980s are documented by Seiford & Thrall (1990). There is the input oriented and output oriented DEA models. The use of DEA In increasing the performance efficiency of food sectors has contributed massively to the improvement of a country economy as well as area.

2.2 DEA Modified Models

DEA is a powerful tool for optimization and measurement of the efficiency of any sectorial unit based on technical and allocative efficiency as mentioned in the previous chapter. It does the comparison of the DMUs (Decision Making Units) to a target on the frontier. In this case, the frontier is the ultimate practice frontier according to the current set of data. Also, DEA is a multiple criteria tool for making a decision, and before it is being applied there is a need for choosing a set of peer units. Therefore, DMU's in DEA, it means they are the units under evaluation or benchmarking viz., farms, firms, hospitals, banks, universities, products, cities, government, airlines and so on. Ultimately, DEA is intended to be a method devised for performance evaluation and benchmarking against best-practice. Alternatively, DEA can also be defined as a relatively new "data-oriented" approach for evaluating performances of set of entities called DMU's which converts sets of inputs into desired outputs. This tool (DEA) allows for use in nonorthodox cases which have been resistant to other parametric analysis approaches due to the complex relations between the inputs and outputs involved in FPI and other commercial sectors, which are often non-commeasurable units.

DEA has also been used in the provision of new insights into activities and entities that have previously been examined by other methods of data analysis [7]. This technique also does not allow the ranking of the efficient unit themselves but evaluate the relative efficiency of decision making. A modified version of DEA based upon a comparison of efficient DMUs relative to a reference technology spanned by all other units are developed. The procedure provides a framework for ranking efficient units and facilitates comparison with rankings based on parametric methods [8]. Among the major area where DEA is important is in the conversion of different inputs into multiple outputs. Such DEA importance as a mathematical programming technique using hospitals as an example is explained below.

In contrast to conventional evaluation methods, DEA as a mathematical programming technique handles sets of inputs and outputs concurrently without assigning random weights to them [9]. For example, certain hospitals generate efficiency boundaries (this is the reason for using the term "Data Envelopment") by using actual inputs and outputs. Therefore, this distance from relative inputs and outputs of other hospitals to these boundaries are then compared to generate a form of scalar efficiency ratio for each hospital. Also distinguishes the resources that are over-utilized by each hospital. DEA can identify objectively the relatively efficient and inefficient hospitals as well as the resources wasted [10].

2.3 DEA Applications in Some Sectors

2.3.1 Application of DEA in the Financial Sector

As mentioned earlier that data envelopment analysis (DEA) as a linear-programming based method for measuring the performance of homogeneous organizational units, this tool is used in the financial sector like banking for the assessment of efficiency performance of the organization. The unit of assessment, in this case, is normally any branch of the bank. Studies are mostly directed in obtaining a summary measure of the efficiency of each unit in the bank, on assessing the targeted performance of the unit, and on the identification of role model units of good operation practice. Besides, DEA is used in the bank for the measurement of efficiency in light of resources and output prices, and also in the assessment of operation budget, financial risk and the impact of managerial change initiatives [8].

2.3.2 Application of DEA in Higher Education

Many countries higher education obtain some of their income from public funds, there is a need for the essential interest of accountability by measuring the efficiency of the institutions which comprise these sectors. Some operation methods of higher education systems make it almost impossible to measure their efficiencies such as non-profit making. For non-profit organization, output and input variables are non-existent, while profitable higher education institutions (HEIs) generate various outputs from input. A case scenario, data (inputs and outputs) collected from of British Universities for the academic year 2000 - 2001 forms the basis of the analysis. Collected data are categorized as either first-degree graduates weighted by their degree classification which is included to capture both the quantity and quality of undergraduates teaching output from the Universities. The total number of graduates from higher degrees i.e. postgraduates is included to give the reflection of the quantity of postgraduate output in the English Universities [11]. The grant for research provided by the Higher Education Funding Council for England (which reflects the Research Assessment Exercise quality rating and the number of research-active staff is similar to the Quantum Research measure used by Avkiran [12] he conducted a study in an Australian university which includes reflecting both on the quality and quantity of research output. The same approach was used to total the average A-level grades of undergraduate entrants and undergraduate numbers as two variables, i.e. input and output measures are comparable in measuring both quantity and quality [13].

2.3.3 Application of DEA in the Food Sector

The food and drink industry is one of the leading manufacturing sectors in the economy of many countries worldwide. Some of the food and drink industry has been facing a persistent decrease in competitiveness in past decades when compared with other food and drink companies worldwide. Therefore, production efficiency can be examined using the DEA model which is defined in terms of data envelopment analysis with inputs as the financial ratio, and outputs in the BCC output-oriented model. Then the findings will reveal which company possessed the highest proportion of efficient production. Efficiency is assessed regarding the capacity of the companies. According to Machmud et al., 2019, data were collected from the leading food industry players in Indonesia (about 16 companies). Data were collected and analyzed using DEA through Constant Return to Scale (CRS) and Variable Return to Scale (VRS) models. The study results showed that the use of food industry production factors in some companies is not yet optimum, confirmed by the VRS and CRS values of less than one. The main reason for the suboptimal production is due to the condition of raw materials and labor, giving ideas for the careful consideration for improving the efficiency in the production are, thus, finding implies that creating efficiency with the Data Envelopment Analysis method needs to optimize the use of raw materials and labor.

Chang et al. [14] applied DEA techniques in analyzing the performance of a Taiwanese bakery. Input and output constructs were used to determined technical and scale efficiency to measure the bakery efficiency loss. Their study pointed that lower pure technical efficiency was as a result of low technical efficiency which sterns form the fact that scale efficiency was higher than pure technical efficiency. They concluded that the bakery is still improving in regards to overall operating and space efficiency. Furthermore, the company's financial performance is dependent upon the producer's ability to stay on the production frontier due to the result of a positive relationship between return on assets (ROA) and technical efficiency.

2.4 Application of DEA in Bakeries

During literature review survey conducted in this study, it was observed that the number of published documents on research concerning the improvement of bakery performance efficiency was very low. On the contrary, studies concerning improving performance efficiencies related to general FPI were abundant and majorly based in China [15-16].

In Qiang and Fang [17], a DEA-based Malmquist method was used to monitor productivity changes in a food industry in China. Their study was related to notice the decrease in efficiency in the mentioned industry.

In a Greece food manufacturing enterprises, Dimara, Skuras, Tsekouras, and Tzelepis [18] applied a DEA approach to compute the technical efficiency values of food companies in Greece. They reported that lifespan of food companies was directly associated to the technical and scale efficiencies of the food companies. Giokas, Eriotis, and Dokas [19] applied DEA to analyze, demand and supply rate of food and beverage companies listed in an Athens Exchange from 2006 to 2012. In a similar analysis regarding food and beverage companies, Rezitis and Kalantz [20] applied a DEA modeling technique, bootstrapped truncated regressions and OLS regressions to evaluate technical efficiency of the above mentioned industry during 1984–2007.

In India, Kumar and Basu [21] applied the Malmquist efficiency index to measure efficiency of food businesses. They reported that inadequate technology of firms impacted a lot regarding their efficiency decline. Similarly, in a study performed by Ali, Singh, and Ekanem [22] for a different food company, they determined inefficiency across various sectors after their DEA study. Performance evaluation of some companies in similar field was measured by Kaur and Kaur in [23] to determine efficiency changes in the year 1988-2011.

The average technical efficiency scores for the food processing industry (FPI) as a whole was noted have experienced declining trends during the whole study period. Investigating efficiency of grain-production in India, Mathur and Raju Ramnath [24] reported a high average efficiency for agriculture sustainability operations after applying DEA and Stochastic Frontier Analysis (SFA) in their study.

Gregg and Rolfe [25] investigated beef production firms in Australia. A strong improvement in productivity due to application of advance technology regarding technical and scale efficiency. In Finland, Holyk [26] in a study discovered food industry sectors with the lowest level of technical and scale efficiency. A study conducted for the US dairy product industry proved that as productivity growth was negative, it had a negative impact on scale and technical efficiency [27].

The use of Two-Stage DEA analysis approach to determine efficiency was demonstrated by Rodmanee and Huang [28] for the Thai food and beverage industry. Their study proved that low overall efficiency score of a company is directly related low efficiency values in the profit generation process.

Some Spaniard food manufacturing industry's dynamic productivity growth was reported in [29]. On the contrary, static productivity growth trend was reported in Kapelko et al. [30] for similar companies in Spain.

Various baked products are considered basic feeding necessities. Hence, the public should be aware of production efficiency in the bakery production industry. It is a well-known fact that DEA applications in other areas is vast and wide, so many applications of DEA by many authors was undergone in different sectors and areas having different situations. The reason why DEA application of some few sectors was reviewed in this research was to give us an idea about how any sectors multiple inputs and outputs can be handled simultaneously without assigning any arbitrary weights them and regardless of the nature of the inputs to output ratio and that u can improve performance of any sector and come out with productive and successful results. Also, literature review done on the financial sector was to give us an idea and understanding of how well operation budgets of a company can be assessed, financial risk and impact of managerial change initiatives and not just production performance food sectors or bakery companies. This can further help the bakery company to further their thinking on improving other aspects of their company by adopting the DEA technique should they chose to do so. This reviews also explains and justifies the successful application of DEA as vast, far and beyond just production frontiers.

Chapter 3

METHODOLOGY

The selection of simple, suitable and appropriate methods for conducting this research is very important and necessary for an efficient, effective and successful research study. The modern evolved tool or mechanism for increasing the energy efficiency of many industrial and food sectors have always been in need, as this will contribute massively in the areas of science and technology as well as economy. Companies such as food Production Company, bakeries in particular, need such mechanism to continuously monitoring of their overall efficiency performance and towards improving the achievements of their companies or industries via conducting their daily, weekly, monthly and yearly productions effectively as well as its performance improvement. This study adopted a sound, suitable and interesting effective benchmark tool as a method for improving such company's total production performance efficiency in order to achieve their current and future goals and objectives.

3.1 Materials and Methods

The methods and materials used in this study will be discuss here. Choosing a suitable, efficient and appropriate materials and methods is necessary to conducting a well-organized, well-structured and successful research or study. In this study, data envelopment analysis (DEA) method/approach was used.

A multi-stage process for comparisons is formulated as listed below:

- Collection of monthly bakery company data (inputs raw materials as well as outputs) for three successive years in the prescribed model of Data Envelopment Analysis (DEA).
- Use DEA for computing the relative efficiency
- Determine the various weights related to the efficiency ranking
- Use Cross Efficiency Method for complete ranking
- Lambdas (λ) method, and lastly
- Talk about the targets method.
- 7 Suggest measures for improvement.

In this research study production raw materials which includes amount of flour used, sugar, water, electricity consumption ,salt, yeast and among others were considered as the input variables while the amount of flour wasted and the final product produced which is the bread were considered as the output variables.

3.2 DEA Standard Models (CCR and BCC)

Since 1978, numerous researchers have reported various DEA models after the first DEA model was developed by Charnes et al. (1978). Different DEA models differ based on their variable orientation (input-oriented, output-oriented), the returns to scale, and types of measures and so on.

There are two main models of DEA which includes the CCR and BCC models. As mentioned earlier, the CCR model was developed by Charne return to scale. It measures the technical efficiency by which decision making units are evaluated based on their performance relative to other decision making units in a sample [31]. CCR model comprehends both scale and technical efficiencies. While on the other hand, the BCC DEA model which was developed by Banker et al (1984) and assumes variable returns to scale conditions. This model decomposes the technical efficiency into a pure technical efficiency for management factors as well as scale efficiency for scale factors. Thus, pure technical efficiency is the technical efficiency that has the effect of scale efficiency removed [32].

In DEA, efficiency is achieved by making and inefficient DMU efficient. This can be done either by reducing the output levels while holding the inputs constant (output oriented) or by reducing the input levels while holding the outputs constant (input oriented). For this research analysis, the input-oriented CCR (Charnes, Cooper and Rhodes, model) [33]. As it is the most suitable and appropriate one. This is deemed to be more appropriate because we are dealing with multiple inputs and only two outputs; also as a recommendation, input conservation for a given outputs seems to be more reasonable and logical. In order to completely analyze the performance efficiency of the bakery company, the Tahir's bakery (bread) and confectionaries data were obtained by collecting the monthly inputs raw materials and outputs that result from the blends of the various raw materials (resources). This inputs and outputs were collected on a monthly production basis for three successive years i.e. from 2016 up to 2018 and the DEA CCR input oriented model was used.

There are many parametric and non-parametric techniques for evaluating performance and productivity efficiency, with the former assuming a single particular functional form between input and outputs as well as statistically estimating the functional parameter as such the knowledge about the functions and error distributions must be known before this technique can be applied while the latter which is DEA happens to be one of the most popular non-parametric technique or approach used in different sectors as benchmarking tool [34] is more suitable and easier to apply due to simplicity and it advantages over the parametric techniques tabulated below:

Table 3.1: Advantages of DEA as a Non-Parametric Technique

Parametric	Non-Parametric
Functional and error distribution functions between inputs and outputs is needed	Assumes neither a preconceived functional relationship imposed between inputs and outputs
Weights of inputs and outputs variables are needed	No prior information about weights of inputs and outputs
	Inputs can be used in different forms of scales
Results usually need further interpretations	Results are represented as percentage efficiency of the maximum scores of the maximum efficiency.

DMU is regarded as the entity responsible for converting inputs into outputs and whose performance are to be evaluated. As such, this advantages that DEA has over the parametric methods makes us to adopt it as the method that will be used for this research.

3.3 Economical Point of View of the CCR Model

DEA approach does not require any assumptions about the functional form of the production function. In the simplest case, where a unit has a single input (X) and output (Y), efficiency is defined as the output to input ratio: Y/X. The DEA usually deals with unit k having multiple inputs $X_{ik}$where i = 1, 2 . . . . $\boldsymbol{m}$ and multiple outputs Y_{rk}, where r = 1, 2 . . ., s, which can be incorporated into an efficiency measure [35]. Where all the parameters under the assumptions are defined as follows;

- k= DMU being evaluated in the set of j=1, 2……n DMUs,
- n= number of DMUs,

- m= number of inputs used by the DMUs,
- s=number of outputs produced by the DMUs
- x_{ij}= the amount of resource input i used by DMU j
- y_{rj}= the amount of output r produced by DMU k
- v_{ik}= the weight assigned to resource input i
- u_{rk}= the weight assigned to output r
- X_{ik}= the amount of resource input i used by DMU k,
- Y_{rk}= the amount of output r produced by DMU k,
- $u \text{ and } v = weights$,
- v_i=weight of input i to be determined,
- u_r=weight of output r to be determined and
- h_k = efficiency measure of the DMU k
- Efficiency measure =$\frac{\text{total weighted sum of the outputs}}{\text{total weighted sum of the inputs}}$. i.e.

$$h_k = \frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}} \tag{3.1}$$

Efficiency eqn. (3.1) requires a set of factor weights u_r and v_i: each DMU k is given a higher efficiency score if h_k=1. This decision is guided by choosing the optimal input and out weights from the available data. For a DMU unit k where h_k= 1 indicate desirable efficiency. For h_k< 1, means the DMU is inefficient. As such, DEA model categorizes DMU's into two groups for which h_k= 1 and h_k< 1 indicating efficient and inefficient DMU's respectively. After categorization, optimization is performed on the inefficient DMUs by decreasing input and increasing output levels.

Data obtained from Tahir bakery and confectionaries was analyzed by using PIM-DEA. This provides the relative efficiencies as well as the cross efficiency of the company's various inputs and outputs as well as their ranking.

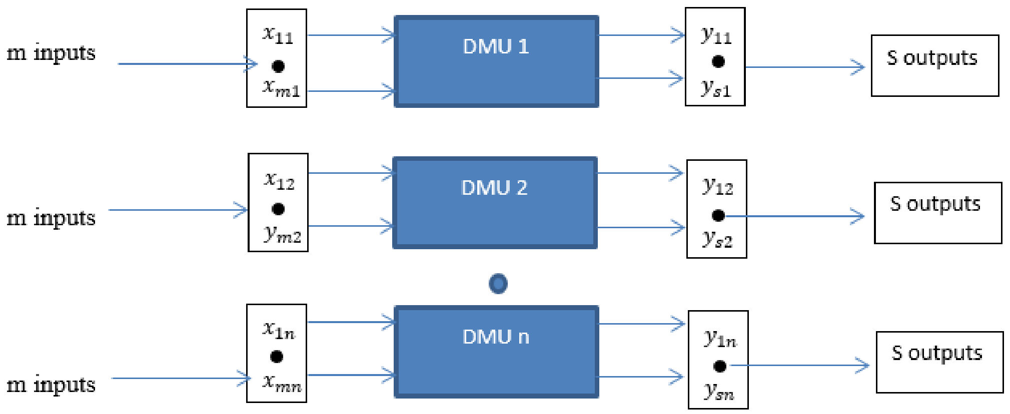

Figure 3.1: Structure of Efficiency Evaluation with Regards to *n* Homogenous DMU

As mentioned earlier, the input oriented CCR model was used for conducting this research and the mathematical model of the CCR model is shown below.

3.4 CCR Model

3.4.1 Fractional Program Form of the Model (FP)

$$\max \theta_k = \frac{\sum_{r=1}^{s} u_{rk} y_{rj}}{\sum_{i=1}^{m} v_{ik} x_{ij}} \theta_k = h_k \tag{3.2}$$

$$subject\ to: \frac{\sum_{r=1}^{s} u_{rk} y_{rj}}{\sum_{i=1}^{m} v_{ik} x_{ij}} \leq 1 j = 1 \dots n, \quad k = 1 \dots n \tag{3.3}$$

$$v_{ik} \geq 0 \qquad i = 1 \dots m \tag{3.4}$$

$$u_{rk} \geq 0 \qquad r = 1 \dots s \tag{3.5}$$

To solve the fractional objective function of the model will be very difficult, therefore, the initial fractional model needs to be converted to its linear form to ease solving. This is done by forcing the denominator to be equal to one, hence making the fractional form to linear form. The linear form of the model will be much easier to solve than the fractional one.

3.4.2 The CCR Model in its Linear Form

$$\max \theta_k = \sum_{r=1}^{s} u_{rk}\, y_{rk}\ \theta_k = h_{kj} \tag{3.6}$$

$$s.t\ \ \sum_{i=1}^{m} v_{ik} x_{ij} = 1 \tag{3.7}$$

$$\sum_{r=1}^{s} u_{rk} y_{rj} - \sum_{i=1}^{m} v_{ik} x_{ij} \leq 0\ j = 1, 2, 3 \ldots n \tag{3.8}$$

$$v_{ik} \geq 0 \quad i = 1,2,3 \ldots m \tag{3.9}$$

$$u_{rk} \geq 0 \quad r = 1,2,3 \ldots s \tag{3.10}$$

The above model represents the linear model of the initial fractional model. The dual of the linear CCR model is then written in its dual form as shown below.

3.4.3 The Dual of the Linear CCR Model

$$min\ \ \theta_k\ \ \theta_k = h_k \tag{3.11}$$

Subject to:

$$\sum_{j=1}^{n} x_{ij}\, \lambda_j \leq\ \theta_k\, x_{ik}, i = 1, 2, \ldots \ldots . m \tag{3.12}$$

$$\sum_{j=1}^{n} y_{rk}\, \lambda_j\ \geq\ y_{rk}, r = 1, 2, \ldots \ldots . . s \tag{3.13}$$

$$\lambda_j \geq 0,\ \ \forall i, j, r \tag{3.14}$$

θ_k = Efficiency measure of the DMU k, λ_j=weight assigned to DMUs

3.5 Cross Efficiency

Cross efficiency is very important and necessary when it comes to finding the complete ranking of the DMU’s in DEA, as such, the Cross Efficiency method was also taken into account.

Decision making units DMUs, specifically the efficient ones are not allowed in the traditional DEA and also in DEA because of the unrestricted weight flexibility problem, it is the possible that some of the efficient units have the overall better performance than the other efficient ones [36]. A well-known method which is the cross efficiency model was initially developed to overcome this problem. The results of all DEA efficiency scores can be aggregated in.

The cross-evaluation matrix was first developed by Sexton et al. [36]. The cross efficiency method compute efficiency values for each DMU n times applying their optimal weights determined by the n LPs. The cross-efficiency equation is represented below.

$$h_{kj} = \frac{\sum_{r=1}^{s} u_{rk} y_{rj}}{\sum_{i=1}^{m} v_{ik} x_{ij}} \quad k = 1,2, \dots n \qquad j = 1,2, \dots n \tag{3.15}$$

Thus, h_{kj} represents the measure of efficiency of DMU k i.e. the DMU in the set of j=1, 2….n DMUS unit j is evaluated by the weights of unit k. y_{rj} represents the amount of service output r produced by DMU k, x_{ij} represents the amount of service input i used by DMUj, u_{rk} represents the weight assigned to service output r computed in the solution of DEA model, v_{ik} represents the weight assigned to resource input i computed in the solution of the DEA model, m represents the number of inputs used by the DMUs and s represents the number of outputs produced by the DMUs. Elements in the cross-efficiency matrix are between zero and one, the diagonal, h_k, represent the standard DEA efficiency score.

3.6 Inputs and Outputs Selection and Definition

Inputs and outputs doesn't refer to inputs and output involved in the production process of manufacturing or agricultural alone, because the definition of output with regards to DEA can be seen as anything you are trying to do or achieve i.e. a particular goal, while those resources used or involved in achieving that particular goal can be called outputs. The whole idea of production is generating valuable outcomes (outputs) at the expense of resources that have alternative uses (inputs) so in as far as the goal and resources used in achieving the goal are quantifiable, they can be used as inputs and outputs in DEA for benchmarking, provided that the production process or plan is feasible.

Selecting the bakery inputs and outputs data for measuring efficiency performance was carefully and appropriately selected, as there are so many things to consider as our outputs and inputs data for this research study such as workers' salaries, transporting expenses of the bakery and more but these data are selected based on how best the company's performance efficiency can be improve with regards to the main raw materials involve especially in the production process of the bread. As such, the selection of such inputs and outputs for improving efficiency performance was done after careful consideration. Moreover, the company's decision makers are more interested in boosting their overall production performance directly involved during the bread production process above all other areas. As such, the DEA concept was adopted and applied over the production resources to help analyze these resource inputs and outputs for performance evaluation of the bakery company. This study's data consisted several input/output variables according to the company's production raw materials data obtained. Two outputs and ten inputs were considered as the decision making units (DMU's) for the past successive three years for this research study. The definitions of these variables are shown in Table 3.2 along with their units:

Table 3.2: Input and Output Variables Definitions Along with their Units

	Item/ raw materials	Unit of Items
A. Input	1. Flour	Kg
	2.Sugar	Kg
	3.Salt	Kg
	4. Yeast	Kg
	5. Butter	Kg
	6. Water	L
	7. Flavor	Kg
	8. Improver	Kg
	9.Milk	Kg
	10. Electricity	kWh
B. Output	1.Bread	Kg
	2. Flour waste	Kg

3.7 Description and Detail of Each Input and Output

3.7.1 Description of the Inputs

1. Flour: the flour here used as one of the inputs refer to the weights of the flour used in kg during production of the bread, this is same flour to which other required ingredients will be added as the inputs to get the appropriate amount and blends required to obtain the final product which is the bread which is consumed.

2. Sugar: the nature of the input here obtained is the weight or amount of the sugar used as one of the blends of ingredients added to the flour in order to give the bread taste and texture along with improving its quality.

3. Salt: also just like bread, the salt used here is the amount of salt that is added to the initial flour used during the process of bread production so as to give the final product the required taste, texture and also can serve as preservative.

4. Yeast: it is one of the inputs used for this research analysis, this input refer to the required amount of yeast which is one of the ingredients added to the blends of flour and water to help the bread rise and also help in developing and strengthening proteins during the bread production. It also helps in breaking down large starch molecules but its main function is to serve as the rising agent in the bread production process.

5. Butter: it is also among the input raw material used, this input refer to the amount of butter used in production of bread, it is added to the blends of different ingredients to obtain the desired output and it is measured in kg. It is added to give the flour blend texture and moisture and also adds protein to the final product.

6. Water: this input refers to the volume of water used in mixing the various blends of ingredients/ raw materials used during the bread production process, it is the total volume of water used in the flour during the process of bread production.

7. Flavor: as the name implies, it is the total amount of flavor used as one of the blends of raw materials or ingredients used for the production of the bread to give it taste, flavor and texture.

8. Improver: it refers to the amount of the company's ingredient used as the improver to give the bread more quality, texture and taste, it is among the company's secret

ingredient or formula used, as such, they refused to reveal what exactly they are using as their improver, but the quantity was given.

9. Milk: this refer to the amount of milk in kg used as one of the ingredient blended with the flour to add texture, taste, color and protein content to the final product during the process of producing the bread.

10. Electricity: Unlike the rest of the inputs used during bread production, this input used for this research study refer to the total amount of units of electricity consumed monthly in the process of bread production. It is measured in kilowatts KWh.

3.7.2 Description of the Outputs

1. Bread: The main output here used refer to the total weight of the bread produced from the blends of various inputs. It refers to the bread which is sold to the market for profit and consumed by customers.

2. Flour waste: Another raw material used as one of the output here refers to the weight or total amount of flour wasted during this bread production, this flour waste includes the flour wasted during mixing and blending, the flour waste obtained as over burnt bread. The total quantity of these wastes is what gives us the second output used for the performance analysis of the company. These monthly inputs and outputs data collected from the company for the past three successive years of production is what give rise to the 36 decision making units (DMUs) which are shown or introduced in the next table to come which is table 3.3 and was further discussed in detail and analyzed in the next chapters to come regarding how the decision making units were used in the performance improvement management software (PIM-DEA) in what nature it was used and what were the possible results

obtained and how these results obtained were analyzed towards how they can help in improving the company's performance efficiency of the bakery company.

The table below shows the 36 decision making units used for this research study; these are the monthly input and output data collected from the bakery company for the past successive three years and the inputs and outputs raw materials are what made up of the 36 decision making units (DMUs).

Table 3.3: Input and Output Data

DMUs	Input 1	Input 2	Input 3	Input 4	Input 5	Input 6	Input 7	Input 8	Input 9	Input 10	Output 1	Output 2
1	31200	975	472.87	39	118	2106	117	8.46	1.17	7223.7	34848	96.34
2	31950	998.43	479.2	40.13	120.81	2156.62	124.5	8.65	1.2	907.01	37023.66	122.33
3	32500	1015.62	512.88	40.63	121.9	2193.8	122	8.71	1.23	807.05	36794.88	111.77
4	32266	1008.31	498.1	40.33	121.97	2179.52	120.99	8.74	1.21	789.22	35436.96	89.66
5	35230	1100.93	552.37	43.87	132.11	2378.03	140.63	9.51	1.32	1081.11	38423.88	97.87
6	33267	1039.59	499	41.18	124.3	2245.52	124.75	8.98	0.15	870.8	35877.78	103.67
7	35984	1124.5	534.13	44.26	134.89	2428.8	143.6	9.73	1.31	733.88	45354.78	99.82
8	34450	1076.56	522.13	43.1	130.36	2326.25	136.4	9.31	1.29	724.77	37310.94	95.22
9	33163	1036.34	523.35	41.2	124.37	2238.5	124.36	8.97	1.24	720.67	36578.16	107.23
10	32266	1008.31	498.2	40.26	120.01	2177.95	120.99	8.71	1.24	1081.11	34797.96	96.36
11	34476	1077.37	533.34	43.09	129.32	2326.21	129.28	9.3	1.29	906.22	37830.78	118.03
12	33371	1042.84	479.9	41.71	125.2	2251.27	125.14	9.12	1.25	728.67	36225.36	47.37
13	34710	1084.68	542.34	43.51	130.05	2342.92	136.53	9.37	1.3	777.02	38087.46	62.99
14	31850	995.31	489.76	39.7	119.34	2149.87	119.43	8.59	1.19	798.66	33523.74	87.66
15	34060	1064.37	510.9	42.57	128.24	2300.25	127.72	9.2	1.27	711.08	33511.5	95.32
16	33605	1050.15	515.56	42	126.01	2268.33	126.01	9.07	1.26	1076.08	36600.48	89.66
17	34125	1066.4	520.5	42.65	130.36	2303.43	136.83	9.26	1.28	822.33	36822.06	90.05
18	32344	1010.7	510.36	40.5	121.3	2183.22	121.29	8.7	1.21	870.22	40550.4	108.96
19	35360	937.7	479.54	37.9	111.97	2025	112.5	8.74	1.16	900.76	33977.88	118.33
20	31122	928.28	490.36	37.13	111.39	2015.08	111.39	8.02	1.11	810.77	34051.14	30.06
21	29705	1101.34	535.74	43.9	133.25	2386.64	148.56	9.51	1.32	763.53	31661.82	77.22
22	35243	1052.59	526.29	42.1	126.13	2273.6	126.31	9.1	1.26	728.77	38379.6	109.33
23	33683	998.96	490.76	39.95	119.87	2157.77	119.87	8.63	1.19	810.88	36219.06	45.55
24	31967	1010.75	500.36	40.43	121.15	2185.27	121.29	8.79	1.22	762.99	35015.58	101.11
25	36153	1129.78	551.37	44.97	140.14	2445.32	147.94	9.79	1.33	873.81	39490.74	90.06

DMUs	Input 1	Input 2	Input 3	Input 4	Input 5	Input 6	Input 7	Input 8	Input 9	Input 10	Output 1	Output 2
26	33501	1046.9	523	42.21	127.73	2261.31	125.62	9.04	1.16	953.77	36667.98	58.22
27	31174	974.18	495.46	38.96	116.9	2108.36	116.9	8.46	1.25	1077.86	34103.7	79.33
28	34554	1079.81	537.25	43.42	129.47	2335.43	129.74	9.13	1.29	758.66	37648.44	97.66
29	34294	1071.68	527.98	42.68	127.94	2314.84	128.6	9.46	1.28	786.36	37032.66	103.33
30	35074	1096.06	548.03	43.48	131.52	2376.26	131.52	9.57	1.31	836.52	38142.18	48.66
31	34099	1065.59	531.35	42.62	127.87	2301.68	127.87	9.5	1.27	1011.66	37454.76	62.99
32	35945	1123.28	551.46	44.93	136.84	2426.28	150.2	9.88	1.34	789.37	39148.92	100.09
33	36413	1020.09	500.36	40.8	122.35	2221.12	129	8.9	1.22	1220.88	38811.6	96.74
34	32643	1100.93	541.36	44.27	132.11	2378.02	136.24	9.6	1.32	1076.36	36853.2	43.97
35	35230	9103.25	557.26	39.97	126.45	245	143.53	9.85	1.29	926.36	34752.6	58.67
36	35074	1096.06	548.03	43.84	131.6	2376.26	139.64	9.46	1.31	778.33	38365.38	105.03

The data shown in Table 3.2 above represent the bread bakery data which comprises of 10 inputs and 2 outputs obtained, various raw materials used as the DMUs from serial numbers 1 to 12 (from January to December), 13 to 24 (from January to December) and 25 to 36 (from January to December also) represent the past/ previous company's yearly production input and output data used from 2016, 2017 and 2018 respectively, both all the inputs and outputs were measured in kilogram (kg) with the exception of two inputs which are: Water that is measured in liters (L) and Electricity units consumed that is measured in kilowatts (KWh).

For further understanding of the importance of this inputs and outputs data to the efficiency of the company, also to have a view about how they are correlated in other words, related to each other, a correlation analysis was done and shown in table 3.4, the reason for conducting the analysis was mainly associated to the selection of flour waste as our second output which need briefing, also, to give reasonable explanation as to why the flour waste was considered as the second output for this study. As such, a correlation analysis on the inputs and outputs data of the company was done.

Table 3.4: Correlation Scores between Inputs and Outputs

DMUs	***Input 1***	***Input 2***	***Input 3***	***Input 4***	***Input 5***	***Input 6***	***Input 7***	***In[ut 8***	***Input 9***	***Input 10***	***Output 1***	***Output 2***
Input 1	**1**											
Input 2	**0.182175**	**1**										
Input 3	**0.530184**	**0.311876**	**1**									
Input 4	**0.491309**	**-0.11731**	**0.798197**	**1**								
Input 5	**0.511161**	**0.051113**	**0.835108**	**0.972815**	**1**							
Input 6	**0.007143**	**-0.9387**	**-0.00339**	**0.450599**	**0.29231**	**1**						
Input 7	**0.479225**	**0.280886**	**0.823116**	**0.84172**	**0.913571**	**0.042276**	**1**					
Input 8	**0.622991**	**0.319003**	**0.859433**	**0.861021**	**0.908875**	**0.012109**	**0.902436**	**1**				
Input 9	**0.173503**	**0.070119**	**0.360874**	**0.30122**	**0.296977**	**0.032352**	**0.318362**	**0.301687**	**1**			
Input 10	**-0.25073**	**-0.02812**	**-0.31651**	**-0.25314**	**-0.22557**	**-0.06217**	**-0.21378**	**-0.25384**	**-0.05006**	**1**		
Output 1	**0.634413**	**-0.12144**	**0.433361**	**0.526513**	**0.51262**	**0.298372**	**0.414531**	**0.443253**	**0.173697**	**-0.13582**	**1**	
Output 2	**0.151344**	**-0.20527**	**-0.07899**	**0.03646**	**0.001561**	**0.196618**	**-0.01073**	**-0.03975**	**-0.09029**	**0.053001**	**0.206512**	**1**

Table 3.4 shows the relationship between each inputs and outputs and how these raw materials are correlated with regards to efficiency of the company, the values ranging from zero to one (0-1), a score of 1 indicates a very strong correlation while those scores below 0.5 indicates a very weak or little correlation, those scores having negative signs represents a negative weak correlation hence suggesting that there is almost no relationship between the inputs or outputs its juxtaposed with or the relationship is negative. It will be noticed that each inputs and output is strongly correlated to itself, thus having a score of 1, those scores highlighted in yellow indicates a slightly weak correlation, while those highlighted in red indicates little or almost no correlation. Looking at output2, it will be observed that it is the one with the most weakly and almost no or very little correlated values, comprising of both positive and negative correlated values. This indicates that output two which is the flour waste is having a very little impact on the efficiency of the company which can be negligible, hence the reason for its consideration and selection as our second output in this research study.

Chapter 4

DATA COLLECTION AND DISCUSSION OF RESULTS

The need for following and explaining the correct, suitable, appropriate and right way of collecting a data and the nature in which it was collected for a study or particular analysis and purpose is very important and necessary, there are several ways for collecting a certain data among which includes; Questionnaires, using online data from the internet i.e. online data which has been previously used by other authors for a certain analysis or directly obtaining the data from a particular company, industry or public sector either via the management or through careful observation and studying a certain company and taking records to get a meaningful data. Some data collected may also come from a case study of particular country or company. The data collected here as mentioned in the previous chapter was obtained directly from the company's manager.

4.1 Description of How the Data was Collected

The data collection for this research study was obtained directly from Tahir's B-Bakery and confectionaries production company which is located in Kaduna Nigeria. The method of the data collection was quantitative in nature and the data were obtained via a discussion with a close family friend who happens to be the company's general manager and the director of the company. The production inputs and outputs resources or raw materials quantities obtained is what made up about 36 decision making units (DMUs), this DMUs which comprises of both the inputs and outputs represented the company's production resources used in producing bread for the past three (3) successive years of the Tahir's bread production i.e. from 2016-2018, the essence is to monitor the technical efficiency performance for these years that have gone through and come up with a suitable, efficient and effective means or ways of improvements regarding their production line and production resources in the near future, regardless of the company's production capacity which will massively help the company in competing well in the current market, improve the country's economy as well as increase the total company's production performance.

The daily total inputs and outputs raw materials used in the production of the bread in the company was taken into account and was compiled at each end of the month from January to December in order to get the total yearly weights or quantities of each raw materials used. The summation of the monthly decision making units (DMUs) is what gave us the total yearly weight or quantity consumed/used for the production of bread in the bakery. Same procedure was followed to get the exact total quantity of the resource raw materials used for each year.

4.2 Normalization Process of the Data

The input and output data summarized in Table 4.1 were collected from the past or previous yearly production of the company from 2016 to 2018 as said earlier. A total of 432 different values were recorded for each of the input and output data showing the nature of the data in each designated month and each and every one of it denoted as a DMU. The input and output data obtained from the company were in different scales as shown in Table 4.1**,** this makes it very difficult to take such data into evaluation. As such, normalization of the data was performed in order to bring it to the same scale for better evaluation towards interpreting the data and calculating efficiency values more easily. This normalization was performed by choosing the highest value for each column of the input and output values and the remaining values in the columns were divided to this highest value selected. Hence by so doing, all the values of the inputs and outputs became in between zeros 0.0 and ones 1.0 Moreover, this normalized data was the data used by the PIM-DEA software which was used for the analysis to test how efficient the company have been and what the possible ways for improving the future performance of the total company's production frontiers are. The normalized data table is shown below.

4.3 Normalized Inputs and Outputs Data Tables

Table 4.1: Normalized Inputs Table

DMUs	input1	input2	input3	input4	input5	input6	input7	input8	input9	input10
DMU01	0.850762	0.107105	0.848563	0.867245	0.842015	0.861237	0.778961	0.856275	0.873134	1
DMU02	0.871213	0.109678	0.859922	0.892373	0.862067	0.881938	0.828895	0.875506	0.895522	0.12556
DMU03	0.886211	0.111567	0.92036	0.903491	0.869844	0.897142	0.81225	0.881579	0.91791	0.111722
DMU04	0.87983	0.110764	0.893838	0.89682	0.870344	0.891303	0.805526	0.884615	0.902985	0.109254
DMU05	0.960652	0.120938	0.991225	0.975539	0.9427	0.972482	0.936285	0.962551	0.985075	0.149661
DMU06	0.907125	0.1142	0.895453	0.915722	0.88697	0.918293	0.830559	0.908907	0.11194	0.120547
DMU07	0.981212	0.123527	0.958493	0.984212	0.962537	0.993244	0.956059	0.984818	0.977612	0.101593
DMU08	0.939383	0.118261	0.936959	0.958417	0.930213	0.951307	0.908123	0.942308	0.962687	0.100332
DMU09	0.904289	0.113843	0.939149	0.916166	0.88747	0.915422	0.827963	0.907895	0.925373	0.099764
DMU10	0.87983	0.110764	0.894017	0.895264	0.856358	0.890661	0.805526	0.881579	0.925373	0.149661
DMU11	0.940092	0.11835	0.957076	0.958194	0.922791	0.951291	0.860719	0.941296	0.962687	0.12545
DMU12	0.909961	0.114557	0.861178	0.927507	0.893392	0.920644	0.833156	0.923077	0.932836	0.100872
DMU13	0.946473	0.119153	0.973226	0.967534	0.928001	0.958124	0.908988	0.948381	0.970149	0.107565
DMU14	0.868486	0.109336	0.878872	0.882811	0.851577	0.879177	0.79514	0.869433	0.88806	0.11056

DMUs	input1	input2	input3	input4	input5	input6	input7	input8	input9	input10
DMU15	0.928749	0.116922	0.916807	0.946631	0.915085	0.940674	0.850333	0.931174	0.947761	0.098437
DMU16	0.916342	0.11536	0.92517	0.933956	0.899172	0.927621	0.838948	0.918016	0.940299	0.148964
DMU17	0.930521	0.117145	0.934034	0.94841	0.930213	0.941975	0.910985	0.937247	0.955224	0.113837
DMU18	0.881957	0.111026	0.915838	0.9006	0.865563	0.892816	0.807523	0.880567	0.902985	0.120467
DMU19	0.964197	0.103007	0.860532	0.842784	0.798987	0.828112	0.749001	0.884615	0.865672	0.124694
DMU20	0.848635	0.101972	0.879948	0.825662	0.794848	0.824056	0.741611	0.811741	0.828358	0.112237
DMU21	0.809996	0.120983	0.961382	0.976206	0.950835	0.976003	0.989081	0.962551	0.985075	0.105697
DMU22	0.961007	0.115628	0.944425	0.93618	0.900029	0.929776	0.840945	0.921053	0.940299	0.100885
DMU23	0.918469	0.109737	0.880666	0.88837	0.855359	0.882408	0.798069	0.873482	0.88806	0.112252
DMU24	0.871677	0.111032	0.897893	0.899044	0.864493	0.893654	0.807523	0.889676	0.910448	0.105623
DMU25	0.985821	0.124107	0.98943	1	1	1	0.984953	0.990891	0.992537	0.120964
DMU26	0.913506	0.115003	0.938521	0.938626	0.911446	0.92475	0.836352	0.91498	0.865672	0.132033
DMU27	0.850053	0.107015	0.8891	0.866355	0.834166	0.862202	0.778296	0.856275	0.932836	0.149211
DMU28	0.942219	0.118618	0.964092	0.965533	0.923862	0.955061	0.863782	0.924089	0.962687	0.105023
DMU29	0.935129	0.117725	0.947457	0.949077	0.912944	0.946641	0.856192	0.95749	0.955224	0.108858
DMU30	0.956398	0.120403	0.983437	0.966867	0.93849	0.971758	0.875632	0.968623	0.977612	0.115802
DMU31	0.929812	0.117056	0.953505	0.947743	0.912445	0.941259	0.851332	0.961538	0.947761	0.140047
DMU32	0.980149	0.123393	0.989592	1	0.976452	0.992214	1	1	1	0.109274
DMU33	1	0.112058	0.897893	0.907272	0.873056	0.908315	0.858855	0.90081	0.910448	0.169009
DMU34	0.89011	0.120938	0.971468	0.984434	0.9427	0.972478	0.907057	0.97166	0.985075	0.149003
DMU35	0.960652	1	1	0.888815	0.902312	0.100191	0.955593	0.996964	0.962687	0.128238

DMUs	input1	input2	input3	input4	input5	input6	input7	input8	input9	input10
DMU36	0.956398	0.120403	0.983437	0.974872	0.939061	0.971758	0.929694	0.95749	0.977612	0.107746
Avg.	0.921357	0.14784	0.932926	0.930324	0.899764	0.89569	0.860566	0.924989	0.937535	0.1212

Table 4.2: Normalized Outputs Table

DMUs	Output 1	Output 2
DMU01	0.768342	0.787542
DMU02	0.816312	1
DMU03	0.811268	0.913676
DMU04	0.781328	0.732936
DMU05	0.847184	0.800049
DMU06	0.791047	0.847462
DMU07	1	0.81599
DMU08	0.822646	0.778386
DMU09	0.806489	0.876563
DMU10	0.767239	0.787705
DMU11	0.834108	0.964849
DMU12	0.798711	0.387231
DMU13	0.839767	0.514919
DMU14	0.739144	0.716586
DMU15	0.738874	0.779204
DMU16	0.806981	0.732936
DMU17	0.811867	0.736124
DMU18	0.894071	0.890705
DMU19	0.749157	0.967302
DMU20	0.750773	0.245729
DMU21	0.698092	0.631243
DMU22	0.846208	0.89373
DMU23	0.798572	0.372353
DMU24	0.772037	0.826535
DMU25	0.870707	0.736205
DMU26	0.80847	0.475926
DMU27	0.751931	0.648492
DMU28	0.830087	0.798332
DMU29	0.81651	0.844682
DMU30	0.840973	0.397777
DMU31	0.825817	0.514919

DMUs	Output 1	Output 2
DMU32	0.86317	0.818197
DMU33	0.855733	0.790812
DMU34	0.812553	0.359438
DMU35	0.766239	0.479604
DMU36	0.845895	0.858579
Avg.	0.804951	0.672967

As shown in Table 4.1 and Table 4.2, the normalized data of both the inputs and outputs were used with utilization of the performance improvement management software known as the PIM-DEA software by using the standard CCR modeling option, several results from the input oriented CCR model were obtained and different values were calculated among which includes the efficiency values, cross efficiency, weights, lambdas as well as target values. The values calculated by the CCR model and given as the results will be further analyzed and discussed in details in the result discussion chapter towards how the company can be more productive by suggesting different ways in which the company can improve its production performance efficiency. The different tables of these results values calculated by the CCR model are given below.

The following table shows how efficient the company have been with regards to each month as this will allow the company to observe how efficient they have been in a particular month and what are the months in which they have been at their maximum efficiently i.e. the months in which overall efficiency was obtained relative to other months.

Table 4.3: CCR Efficiency Results of Each DMU

YEAR 2016	EFFICIENCIES
DMU01 JANUARY	92.51
DMU02 FEBRUARY	100
DMU03 MARCH	99.38
DMU04 APRIL	89.16
DMU05 MAY	86.9
DMU06 JUNE	100
DMU07 JULY	100
DMU08 AUGUST	92.06
DMU09 SEPTEMBER	100
DMU10 OCTOBER	88.07
DMU11 NOVEMBER	96.04
DMU12 DECEMBER	90.4
YEAR 2017	EFFICIENCY
DMU13 JANUARY	87.22
DMU14 FEBRUARY	85.55
DMU15 MARCH	89.81
DMU16 APRIL	88.04
DMU17 MAY	86.04
DMU18 JUNE	100
DMU19 JULY	100
DMU20 AUGUST	91.55
DMU21 SEPTEMBER	84.79
DMU22 OCTOBER	100
DMU23 NOVEMBER	91.56
DMU24 DECEMBER	94.84
YEAR 2018	EFFICIENCY
DMU25 JANUARY	86.74
DMU26 FEBRUARY	88.57
DMU27 MARCH	87.38
DMU28 APRIL	92.46
DMU29 MAY	93.51

DMU30 JUNE	88.68
DMU31 JULY	88.14
DMU32 AUGUST	90.86
DMU33 SEPTEMBER	94.94
DMU34 OCTOBER	89.57
DMU35 NOVEMBER	100
DMU36 DECEMBER	94.49

Efficiency values in Table 4.3 were represented in percentage i.e. from 100% downwards, the measure in % indicates how well the company have performed and at what month have they used their maximum resources efficiently. The 100s in the efficiency table (table 4.3) shows that the DMUs that corresponds to a particular month is 100% efficient, indicating that the company have used all the available production inputs to their optimal point while those efficiency scores that are not up to 100% means that the inputs or resources used were not used optimally which means some of the inputs have been wasted and might not necessarily be needed in during the production process, the value of a corresponding inefficient DMU in a particular month obtained from the difference of 100 represents the percentage of the resource input wasted or should not have been used so as to achieve a better efficiency performance. As such, with regards to table 4.3, the efficient DMU values recorded were DMU2 (the 2nd month of the year 2016), DMU6 and DMU7 (the 6th and 7th month of the year 2016 respectively), DMU9 (the 9th month of the year 2016), DMUs 18 and 19 (the 6th and 7th month of the year 2017 respectively), DMU22 (the 10th month of the year 2017) and DMU35 (the 11th month of the year 2018). Apart from the efficient DMUs mentioned i.e. DMUS with the scores of 100, the closest efficient DMU value of the company recorded was DMU3 (the 3rd month of the year 2016) with efficiency value of 99.38 which shows that about 0.62% of the company's resource inputs have been wasted or should not have been used. Moreover, it was observed that the least or minimum efficient DMU of the past company production resource input is DMU21 (the 9th month of the year 2017) with an efficiency score of 84.79 which means that 15.21% of the inputs should have been used or are wasted. All other remaining DMUs are to be analyzed in the same way or manner with regard to table 4.3.

In consideration to how efficient the company have been overall and given the fact that the least input efficiency value recorded in table 4.3 happens to be 84.79% shows that the company are relatively doing good when it comes to utilizing their input production resources in order to obtain their outputs product. However, the aim and target of any growing company or industry or organization, is to achieve perfection through utilizing their resource inputs optimally i.e. by using the maximum available inputs (100%) and such goals and target is what the company is thriving to achieve hence the essence of this thesis research study.

4.4 Histogram Frequency Distribution of the Efficiency Results

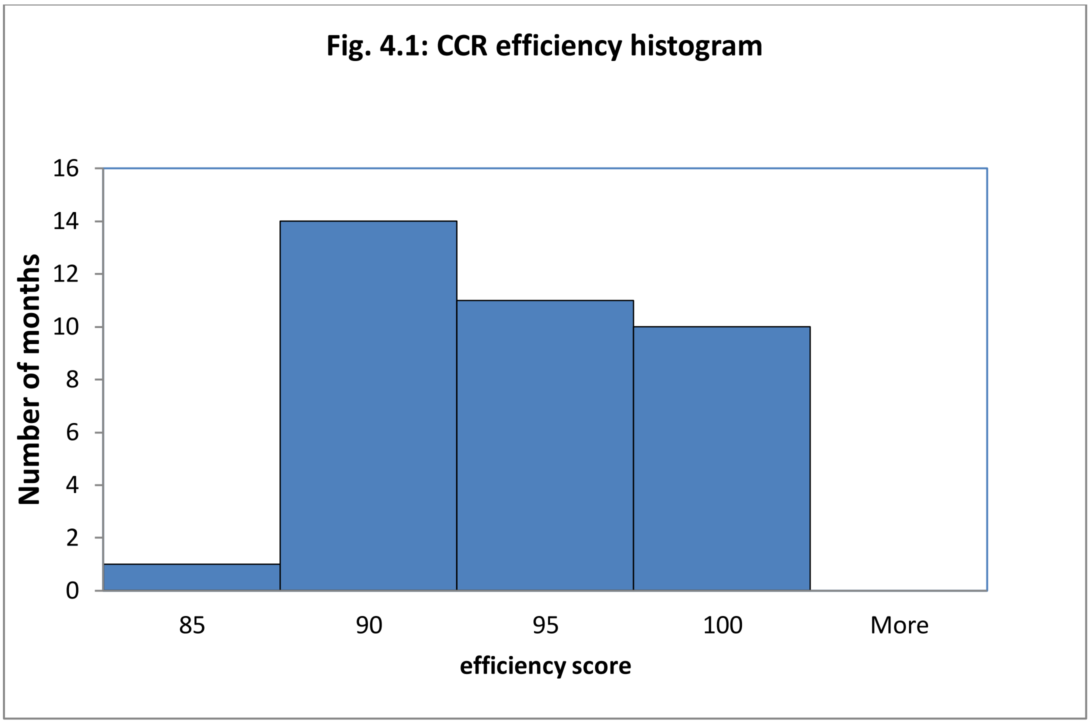

Figure 4.1: CCR Efficiency Histogram

As shown in the above efficiency histogram, the company are no doing badly when it comes to utilizing their inputs and outputs production resources, with the minimum of their efficiency score during the entire period of the previous 3 years data obtained being at 85%. Although they have been 100% efficient on several occasions as shown in the above histogram score, they have been at their maximum in 10 months over the course of the years which show that they are slightly optimal during those periods. Most of the company efficiency score is between 90 to 95, which is a good score to have but given the fact that the aim of any firm is continual and gradual growth of its company, as well as making the maximum of their available input and output resources, there is a lot of room for improvement regarding the company's overall performance efficiency since the aim is to reach the optimal limits by using less inputs to achieve maximum outputs.

4.5 Analysis of the CCR Weights (u and v)'s

After the efficiency score table, the next table to be discussed is the weights table generated by the software, this table entails various weights of the inputs and outputs. The weight method shows the contribution of each DMU and shows the most significant DMU i.e. the DMU with most contribution in regards to efficiency, it also shows which DMU has the least contribution related to improving the overall production performance. The weight table of both the input and output is given below.

Table 4.4: CCR Input Weights (v)'s

Name	input1	input2	input3	input4	input5	input6	input7	input8	input9	input10
DMU01	0	0	0.92	0	0	0	0.28	0	0	0
DMU02	0	0	0.57	0.45	0	0	0	0	0.12	0
DMU03	0.43	0	0	0	0	0	0.27	0	0	3.52
DMU04	0	0	0	0	0	0	1.02	0	0	1.63
DMU05	0	0	0	1.03	0	0	0	0	0	0
DMU06	0	0	0	0	0	0.36	0.78	0	0.2	0
DMU07	0	0	0	0.84	0	0	0	0	0.17	0
DMU08	0.42	0	0.15	0	0	0	0	0	0	4.57
DMU09	0.42	0	0	0	0	0	0.1	0	0.14	4.08
DMU10	0	0	0.88	0	0	0	0.27	0	0	0
DMU11	0.08	0	0	0	0	0	0.7	0	0	2.58
DMU12	0	0	0.53	0	0	0	0.66	0	0	0
DMU13	0	0	0	0	0.98	0	0.1	0	0	0
DMU14	0	0	0.35	0	0	0	0.47	0	0	2.85
DMU15	0.43	0	0.15	0	0	0	0	0	0	4.65
DMU16	0	0	0.51	0	0	0	0.63	0	0	0
DMU17	0.45	0	0.62	0	0	0	0	0	0	0
DMU18	0	0	0	0.96	0	0	0	0	0.15	0
DMU19	0	0	0	0	0.31	0	0.4	0	0.13	2.76

Name	input1	input2	input3	input4	input5	input6	input7	input8	input9	input10
DMU20	0	0	0	0.87	0	0	0.38	0	0	0
DMU21	1.23	0	0	0	0	0	0	0	0	0
DMU22	0.34	0	0	0	0	0	0.26	0	0.12	3.36
DMU23	0	0	0.53	0	0	0	0.66	0	0	0
DMU24	0.45	0	0	0	0	0	0.28	0	0	3.63
DMU25	1.01	0	0	0	0	0	0	0	0	0
DMU26	0	0	0.4	0	0	0	0.59	0	0.15	0
DMU27	0	0	0	0.83	0	0	0.36	0	0	0
DMU28	0	0	0	0	0	0	0.02	0.73	0	2.93
DMU29	0.42	0	0	0	0	0	0.27	0	0	3.44
DMU30	0	0	0	0	0	0	0.94	0	0	1.5
DMU31	0	0	0.5	0	0	0	0.62	0	0	0
DMU32	0.59	0	0	0	0	0	0	0	0	3.9
DMU33	0	0	0.67	0	0.45	0	0	0	0	0
DMU34	1.12	0	0	0	0	0	0	0	0	0
DMU35	0.79	0	0	0	0	0.32	0	0	0.22	0
DMU36	0.4	0	0	0	0	0	0	0.2	0	3.97
Total weights	8.58	0	6.78	4.98	1.74	0.68	10.06	0.93	1.4	49.37

as seen in Table 4.4 of the inputs weights, most significant of the input DMUs are those with highest total weight for example, the significant DMUs i.e. the DMUs who has the most contributions to the efficiency performance are input1, 3, 4, 7 and 10 with total weights of 8.58, 6.78, 4.98, 10.06 and 49.37 respectively, but input 10 is the most significant of them all as such total deposits of input resources should be more considered on input 10 for increasing the company's efficiency, by so doing, efficiency of the company will be much more improved than by deciding to increasing the efficiency of input 1,3,4 and 7. Moreover, it was observed that input2 has no any effect on the company's efficiency with a total weights of zero (0) and the less significant input or the input with less contribution to the efficiency of the company happens to be input6 with 0.68 total weights. Moreover, with reference to the correlation scores in Table 3.4, it will also be observed that inputs 1,3,4 and 7 are having a very strong and positive correlated values hence, further indicating that these DMUs and having a significant impact on the efficiency of the bakery company.

Table 4.5: CCR Output Weights (u)'s

Name	output1	output2
DMU01	0.94	0.25
DMU02	0.87	0.29
DMU03	0.57	0.58
DMU04	1.14	0
DMU05	0.9	0.13
DMU06	1.26	0
DMU07	1	0
DMU08	0.45	0.71
DMU09	0.52	0.66
DMU10	0.9	0.24
DMU11	0.47	0.59
DMU12	1.13	0
DMU13	1.04	0
DMU14	0.66	0.51
DMU15	0.46	0.72
DMU16	1.09	0
DMU17	0.84	0.24
DMU18	0.97	0.15
DMU19	0.57	0.59
DMU20	1.22	0

Name	output1	output2
DMU21	1.18	0.04
DMU22	0.57	0.57
DMU23	1.15	0
DMU24	0.59	0.6
DMU25	0.97	0.03
DMU26	1.1	0
DMU27	1.16	0
DMU28	0.6	0.53
DMU29	0.56	0.57
DMU30	1.05	0
DMU31	1.07	0
DMU32	0.46	0.62
DMU33	0.87	0.26
DMU34	1.1	0
DMU35	1.31	0
DMU36	0.47	0.63
Total weights	31.21	9.51

Same thing applies to the output weights, the total outputs weights calculated for each DMU represents the contribution of each output DMU to the efficiency performance and improvement of the company. Looking at table 4.5, it will be observed that both the two inputs i.e. input 1 and 2 have a significant effect on the efficiency both with a total weights of 31.21 and 9.51, but the most significant of the outputs happens to be output one which is final product produced (bread). It is obvious that the bread produced should have more impact on the production efficiency than the amount of flour wasted in form of damaged bread and wasted flour during production process which is output 2. As such, it will be more advisable and effective for the company to focus on improving the efficiency of output 1 rather than output 2 because it has more effect to the efficiency than output 2.

4.6 Sensitivity Analysis of the CCR Weights

The sensitivity analysis about the weights efficiency results obtained was undergone in order to analyze the changes and significant effects of the efficiencies of the weight used in the forecasted weights of the inputs and outputs of the years under the assumption. The analysis involves in the total summation of each of the inputs and outputs column to determine how sensitive those inputs and outputs are. This analysis will help the company to answer questions related to how reliable, efficient and significant their inputs and outputs are and which one is the most significant of the outputs or inputs used, thus, contributing to the targets set by the company towards improving the performance efficiency of their outputs and inputs resources used. After the sensitivity analysis of the weights results in Table 4.4 and 4.5 (i.e. the u and v) tables, it will be noticed that in the input table, input 1, 7 and 10 are among the highest significant inputs, but the most significant of the inputs is input 10 thus, suggesting that attention should be given more towards improving its efficient use. Moreover, if we take a look at the outputs table (Table 4.5), it will be seen clearly that output1 (final product in form of bread) is far way more significant than output2 (waste flour and over burnt bread) which is obvious because output2 is slightly related or dependent on output1.

4.7 Cross Efficiency Analysis

The next table to be discussed after computing and analyzing the weight tables is the cross efficiency table. The cross efficiency table is computed by using the weights of all efficient DMUs. This efficient DMUs weight was used in chapter three to compute the fraction of the cross efficiency i.e. the fraction in eqn. (3.15) this fraction simply calculates the efficiency score of each DMU n times, using the optimal weights evaluated by the n LPs. a lot have been discussed about the cross efficiency in the previous chapter i.e. chapter 3. The analysis of this table try to solve the problem regarding which DMU among the efficient DMUs should be used for benchmarking since the aim of any organization is to achieve optimal productivity and performance. The cross efficiency table is very long and bulky as such some of the cross efficiency score are given below and will be analyze and discuss briefly after. The complete cross efficiency table is shown in the appendices section.

Table 4.6: CCR Cross Efficiencies

Name	DMU01	DMU02	DMU03	DMU04	DMU05	DMU06	DMU07	DMU08	DMU09
DMU01	92.51	100	92.77	88.02	85.3	90.94	100	87.15	89.66
DMU02	91.58	100	93.15	87.33	86.32	100	100	87.06	90.23
DMU03	21.82	100	99.38	88.34	79.03	90.3	100	91.34	99.95
DMU04	36.19	88.69	91.58	89.16	80.62	86.47	100	86.11	91.35
DMU05	89.57	94.83	91.94	87.11	86.9	87.85	100	85.91	89.69
DMU06	89.05	90.41	90.08	87.55	83.97	100	97.49	83.77	87.98
DMU07	87	89.87	88.03	85.55	85.23	100	100	84.32	86.39
DMU08	17.83	100	98.47	86.21	76.19	89.08	100	92.06	100
DMU09	19.86	100	98.9	87.14	77.84	100	100	91.54	100
DMU10	92.51	100	92.77	88.02	85.3	90.94	100	87.15	89.66
DMU11	25.87	100	99.26	87.39	77.89	90.41	94.36	87.33	98.63
DMU12	90.8	92.72	90.25	88.52	84.4	88.1	100	85.5	87.97
DMU13	88.41	91.42	90.28	86.97	86.5	86.31	100	85.26	87.98
DMU14	25.9	100	97.89	88.6	79.63	91.05	100	90.2	97.63
DMU15	17.83	100	98.47	86.21	76.19	89.08	100	92.06	100
DMU16	90.8	92.72	90.25	88.52	84.4	88.1	100	85.5	87.97
DMU17	91.78	100	92.89	87.59	86.32	90.05	100	87.45	89.73
DMU18	89.54	94.96	91.86	87.02	86.78	100	100	85.86	89.66
DMU19	26.24	100	98.59	87.34	79.48	100	97.16	88.62	98.12

DMU20	89.2	91.22	90.38	87.72	85.78	86.73	100	85.1	88.48
DMU21	89.16	93.05	90.65	87.45	86.86	86.21	100	86.26	88.21
DMU22	22.57	100	99.05	88.19	79.28	100	100	91.01	99.54
DMU23	90.8	92.72	90.25	88.52	84.4	88.1	100	85.5	87.97
DMU24	21.82	100	99.38	88.34	79.03	90.3	100	91.34	99.95
DMU25	89.16	93.05	90.65	87.45	86.86	86.21	100	86.26	88.21
DMU26	90.4	92.33	90.11	88.29	84.52	100	100	85.32	87.98
DMU27	89.2	91.22	90.38	87.72	85.78	86.73	100	85.1	88.48

The above table shows some of the efficient DMUs utilized by the cross efficiency method. When we analyze the part of the cross efficiency table (table 4.6) given it will be noted that all the values given ranges from 17 – 100, although most of the values are relatively efficient with efficiency score ranges between 80 – 100. The 100 score in the table represent those DMUs that are optimally efficient hence the DMUs which are fair indicating that they have an overall better performance than the other efficient decision making units (DMUs). Looking at DMU1 to DMU9, it will be observed that the column that has more values of cross efficiency range of 100 is DMU7 which is the fair DMU and the suitable candidate to be selected as benchmark for others.

4.8 CCR Lambdas (λ) Analysis

The lambdas in the table below illustrated how each DMU is juxtaposed together particularly the inefficient DMUs. The DMUs lambdas (λ) which can also be called weights table, shows the λ score of how all the inefficient company's resource (DMUs) can make itself more efficient by comparing itself to the most efficient DMU in which it is juxtaposed with in the table, this efficiency values were calculated and shown in the next table to come. The essence of the lambdas (λ) method is to find one or several of the DMUs that are at their most efficient in relation to production performance, and set them as the benchmark or reference for improving the other less efficient DMUs observed at a particular moment, this is necessary in order to improve the overall company's performance efficiency. As shown earlier in chapter 3, λ amount can be calculated through solving the dual model of the linear programming CCR model. The table is as follows and will be analyzed and briefly discussed immediately after.

Table 4.7: CCR Lambdas (λ)

Name	DMU02	DMU06	DMU07	DMU09	DMU18	DMU19	DMU22	DMU35
DMU01	0.23	0	0.11	0	0.53	0	0	0
DMU02	1	0	0	0	0	0	0	0
DMU03	0.48	0	0.02	0	0.08	0	0.39	0
DMU04	0	0	0.24	0	0.61	0	0	0
DMU05	0	0	0.24	0	0.67	0	0	0
DMU06	0	1	0	0	0	0	0	0
DMU07	0	0	1	0	0	0	0	0
DMU08	0.02	0	0.42	0.3	0	0	0.17	0
DMU09	0	0	0	1	0	0	0	0
DMU10	0.16	0	0.04	0	0.67	0	0	0
DMU11	0.57	0	0	0	0.16	0.08	0.2	0
DMU12	0	0	0.6	0	0.22	0	0	0
DMU13	0	0	0.65	0	0.21	0	0	0
DMU14	0.02	0	0.14	0	0.61	0	0.05	0
DMU15	0.02	0	0.02	0.07	0	0	0.76	0
DMU16	0	0	0.18	0	0.7	0	0	0
DMU17	0.03	0	0.44	0	0.39	0	0	0
DMU18	0	0	0	0	1	0	0	0
DMU19	0	0	0	0	0	1	0	0
DMU20	0	0	0.02	0	0.82	0	0	0
DMU21	0	0	0.36	0	0.38	0	0	0
DMU22	0	0	0	0	0	0	1	0

Name	DMU02	DMU06	DMU07	DMU09	DMU18	DMU19	DMU22	DMU35
DMU23	0	0	0.18	0	0.69	0	0	0
DMU24	0.38	0	0.17	0	0.02	0	0.32	0
DMU25	0	0	0.73	0	0.16	0	0	0
DMU26	0	0.07	0.04	0	0.79	0	0	0
DMU27	0	0	0.02	0	0.82	0	0	0
DMU28	0.03	0	0.3	0	0.19	0	0.4	0
DMU29	0.22	0	0.18	0	0.1	0	0.44	0
DMU30	0	0	0.32	0	0.58	0	0	0
DMU31	0	0	0.08	0	0.83	0	0	0
DMU32	0.15	0	0.51	0.29	0	0	0	0
DMU33	0.04	0	0.38	0	0.5	0	0	0
DMU34	0	0	0.81	0	0	0	0	0
DMU35	0	0	0	0	0	0	0	1
DMU36	0.15	0	0.28	0.49	0	0	0.06	0

If we closely take a look at table 4.6, the analysis of the table shows how DMUs are being juxtaposed with most emphasis on comparing the inefficient ones to the efficient DMUs. The main aim here is to show which particular efficient DMU can serve as a benchmark to the inefficient ones, in order words, which efficient DMU should be seen as the benchmark for other inefficient DMUs to adopt of follow its way in becoming more efficient. This gives the company view of what way to follow in increasing a particular DMU and what are the possible DMUs that will serve as the benchmark for such efficiency improvement and above all, it shows which efficient DMU can give the best result when set as a benchmark for other inefficient DMUs. As if we look at the table (table 4.6), it will be observed that the values recorded for each DMU ranges from 0 to 1, The DMUs with a score of 1 indicates that a particular DMU is efficient, and those with the value of zero (0) shows that the DMUs need not to compare itself or employ any method used from other efficient DMUs. However, with regards to table 4.6, DMU01 is being referred to DMUs 2, 7, and 18 (λ_2, λ_7, λ_{18}) with λ scores of 0.23, 0.11 and 0.53 respectively. This indicates that DMU01 can adopt the method used by the above mentioned lambdas (λ) i.e. their performances regarding the production process to become efficient, with most emphasis given to λ_{18} i.e. DMU18 because it is the DMU with the highest value of λ. All other DMUs that are juxtaposed are to be analyzed in the same manner. Moreover, it was observed that the lambdas values of DMU2, DMU7, and DMU18 (λ_2, λ_7, λ_{18}) have been referred to the most with total number of 14, 28, and 24 respectively by all the 36 DMUs. This shows that the aforementioned values of DMU lambdas (λ) are the benchmarks for which inefficient DMUs can become efficient and that DMU7 (λ_7) is most referred DMU of them all with a total number of 28 DMUs using it as a reference or benchmark.

4.9 CCR Model Targets Analysis

As the name implies, this method utilized by DEA helps to set target at each month regarding the measure of how much of the current input used should be decrease in each month for increasing the total output efficiency at that particular month. The CCR model targets table is shown in the appendices B**,** the point of the target analysis is it to give the company a view of how much of their inputs production resources can be decrease in each particular month to increase their total output resources at a particular month. This is very important and necessary for the company towards achieving their goal in improving the total company's production capacities. Also, if we refer to the targets table shown in appendices B, it will be observed that the targets set for all the inputs to be used are less than the current inputs used by the company, thus indicating that there is a room for decreasing the amount of inputs used in producing the outputs, which ultimately means that some of the inputs are being wasted along the production process. While in regards to the outputs, targets are more than the outputs meaning that the total output produced can be improve to a certain percent regarding each DMU used. This means that DEA act in such a way by encouraging each of DMUs to set suitable targets for which when followed will increase and improve the current efficiency values or situation of the inputs and outputs used. Hence, adding value to the overall production process and increasing the percentage of the value obtained. Moreover, the measure of the efficiency value is also given under the assumption that the targets sets are being followed.

Looking at the targets appendices (Appendices B) and making reference to DMU1 (January, 2016), when analyzed, it was noticed that the value of input1 with 0.85, should be reduced to 0.77 for better efficiency performance. Hence indicating that 0.77 is the target value for DMU1 when it comes to minimizing the wastage of their resource inputs. This shows that if the company decide to use the target value given for input 1 (DMU1), the will save about 0.08 of their initial input resources used which is wasted and the percentage (%) efficiency value of the input will increase by -9.22 %. The rest of the values in the appendices are to be analyzed in a similar way for improving the overall performance efficiency of the bakery.

The different analysis of the CCR results tables done is summarized here and how the analysis of the tables' means regarding the overall company's performance efficiency, also, the results can help contribute towards improving the areas where the company have been less efficient or where they have lower performance.

However, some recommendations will also be given at the end to the company regarding improving their total performance efficiency more and how to sustain it.

4.10 Results Discussion

After the analysis of the different CCR input oriented results obtained in the previous chapter, the main efficient inputs and outputs DMUs are highlighted as the benchmarked DMUs for the other lesser efficient DMUs. This will help reduce the amount of resources wasted and therefore curbing inefficient utilization of resources. As seen from the efficiency result, the best months in which the company have been at their optimum when it comes to performance efficiency for the past years of production from 2016 to 2018 have been DMU2 (2nd month of the year 2016) which is February, DMUs 6 and 7 (6^{th} and 7^{th} month of the year 2016) i.e. June and July respectively, DMU9 (9^{th} month of the year 2016) i.e. September, DMUs 18 and 19 (6^{th} and 7^{th} month of the year 2017) i.e. June and July respectively, DMU22 (the 10^{th} month of the year 2017) i.e. October and lastly DMU35 which is the 11^{th} month of the year 2018. This named DMUs production performance should be adopted by other DMUs in the future as benchmark DMUs for improving the company's overall performance.

However, based on the results obtained from the summarized efficiency tables, it can be observed that the company are doing relatively alright when it comes to performance efficiency and utilization of their resources with an overall average efficiency score of 92.4 from the previous years, however, as years progress , the performance production efficiency have been declining from 2016 to 2018, with 2018 having the lowest efficiency score on average among the three previous years as shown in Table 5.1 this means that there is a tendency for further dropping of efficiency in the future productions to come, for this reason. Some recommendations are given below for the company to follow in order to avoid further future efficiency from dropping and improve and sustain the future production performance efficiency.

This will also help them stay active and compete well in the current market, plus the fact that the goal of any firm is to achieve maximum outputs with less inputs in order words reach optimality level, this shows that there is room for lots of improvements.

Table 4.8: Average Efficiency Scores of Each Year

Months	Year 1, 2016 efficiency score (DMU 1 to 12)	Year 2, 2017 efficiency score (DMU 12 to 24)	Year 3, 2018 efficiency score (DMU 24 to 36)
January	92.51	87.22	86.74
February	100	85.55	88.57
March	99.38	89.81	87.38
April	89.16	88.04	92.46
May	86.9	86.04	93.51
June	100	100	88.68
July	100	100	88.14
August	92.06	91.55	90.86
September	100	84.79	94.94
October	88.07	100	89.57
November	96.04	91.56	100
December	90.4	94.84	94.49
Average scores.	94.54333	91.61667	91.27833

By taking the year 2018 as a reference year because it is the year with the lowest average score, and using the results obtained from the CCR targets, here some recommendations for which the company will follow for boosting the efficiency and minimize wastage of resources as well as solve the problem of the decline in efficiency in the future.

4.11 Recommendations

Below are summarized monthly table of inputs and outputs recommended for the company to use regarding their inputs and outputs raw material usage for a better performance towards increasing efficiency by avoiding wastage of resources in the future and solving the issue of further dropping of efficiency. Also to add value to the company, the following recommendations should be followed by the company.

Table 4.9: Monthly Recommendation for Future Productions

Months	Input1	Input2	Input3	Input4	Input5	Input6	Input7	Input8	Input9	Input10	Output1	Output2
January	0.77	0.1	0.79	0.97	0.76	0.78	0.72	0.77	0.79	0.1	0.77	0.79
February	0.87	0.11	0.86	0.89	0.86	0.88	0.83	0.88	0.9	0.13	0.82	1
March	0.88	0.11	0.87	0.88	0.85	0.87	0.81	0.87	0.89	0.11	0.81	0.91
April	0.77	0.1	0.78	0.92	0.89	0.92	0.83	0.91	0.11	0.11	0.79	0.85
May	0.9	0.11	0.94	0.94	0.9	0.93	0.96	0.98	0.98	0.1	1	0.82
June	0.96	0.12	0.94	0.94	0.9	0.93	0.83	0.91	0.93	0.12	0.85	0.89
July	0.96	1	1	0.89	0.9	0.1	0.84	0.92	0.94	0.9	0.77	0.48
August	0.94	0.11	0.86	0.87	0.84	0.87	0.96	1	0.96	0.9	0.82	0.78
September	0.9	0.11	0.94	0.92	0.89	0.92	0.9	0.11	0.94	0.08	0.81	0.88
October	0.77	0.1	0.79	0.78	0.75	0.78	0.77	0.1	0.79	0.11	0.77	0.79
November	0.9	0.11	0.89	0.9	0.87	0.89	0.9	0.11	0.89	0.11	0.83	0.96
December	0.78	0.1	0.78	0.79	0.77	0.79	0.78	0.1	0.78	0.11	0.8	0.69

Table 4.9 above gives the company suitable ways on how the make use of their inputs at minimum while achieving maximum outputs at the same time.

The summary in Table 4.9 gives the company many suitable ways on how they can use their available inputs efficiently and avoid future wastage of resources involved in generating their desired outputs. It will also solve the problem of the decline of efficiency in the near future years of production to come.

Chapter 5

CONCLUSION AND FUTURE STUDY

5.1 Conclusion

In conclusion, DEA analysis technique is undoubtedly once again justified its selection for this research and also as one of the robust analysis technique used over other multiple criteria decision methods due to its ability to handle unlimited number of criteria and the simplicity in its evaluation methodology and also one of the most adopted and simple technique for benchmarking. The results also shows that Tahir Bakery are not doing very bad when it comes to production efficiency performance with a total average efficiency score of about 94%, but it is a well-known fact that every firms goals is to make the maximum of their inputs in the least possible ways for obtaining the desired or maximum output, also regarding the bakery efficiency results, it was observed that the company's performance based on the efficiency have been slightly dropping as the years goes on, therefore for the company to sustain their efficiency, curve future efficiency decline, compete in the current market, boost the country's economy as well as provide food to the people in an efficient manner , the monthly recommendations suggested for the company should be followed to achieve their set goals and boost the overall company's performance efficiency.

5.2 Suggestions for Future Studies

Over the course of this thesis research study, especially in the literature review chapter, it was noticed that very little or few journals are related to improving the bakery performance efficiency using DEA were found. Most of the journals focus more on food sectors In General such as beverages Production Company, soya oil production, wheat production and Oil Company's as such further research on improving the performance of bakeries using DEA should be conducted by authors. Moreover, since the company are performing really good regarding the efficiency performance of the bakery, other research related to the relationship between the aim of this research which is producing bread to the people in an efficient manner to the output which is effectiveness, this means conducting research on where the bakery is located or situated to know how effective the bakeries are in relation to their efficiency is necessary because even if the bakery is 100% efficient overall, while there is relatively low population regarding where the bakery is situated, then the bakery might be efficient but not effective. Therefore, the aim can't be efficient unless its effective as well 100%, a typical example is a bakery that is 100% efficient in all areas regarding the production process, but located on an isolated place with less population e.g. at the top of a mountain. Another future area of study is the relationship between the aim and the input which is productivity, for example is the water supplied by the government and taxes paid involved and bills paid for both water and electricity consumption used as part of the inputs, if u take all this into account, will the company still be productive? As such, further research should be conducted in such areas related to bakeries.

REFERENCES

[1] Rafiee S, Mousavi Avval SH, Mohammadi A. Modeling and sensitivity analysis of energy inputs for apple production in Iran. Energy 2010; 35(8):3301-6.

[2] Sherman HD. Service organization productivity management. Hamilton, Ontario: The Society of Management Accountants of Canada; 1988.

[3] Mukherjee K. Energy use efficiency in the Indian manufacturing sector: an interstate analysis. Energy Policy 2008; 36(2):662-72.

[4] Singh G, Singh S, Singh J. Optimization of energy inputs for wheat crop in Punjab. Energy Conversion and Management 2004; 45(3):453-65.

[5] De Jonge AM. Eco-efficiency improvement of a crop protection product: the Perspective of the crop protection industry. Crop Protection 2004; 23(12):1177-86

[6] Esengun K, Erdal G, Gunduz O, Erdal H. An economic analysis and energy use in stake-tomato production in Tokat province of Turkey. Renewable Energy2007; 32:1873-81.

[7] Cooper, W.W., Seiford, L.M. and Tone, K., 2000. Data envelopment analysis. *Handbook on Data Envelopment Analysis, 1st ed.; Cooper, WW, Seiford, LM, Zhu, J., Eds*, pp.1-40.

[8] Boussofiane, A., Dyson, R.G. and Thanassoulis, E., 1991. Applied data envelopment analysis. *European Journal of Operational Research*, *52*(1), pp.1-15.

[9] Charnes, A., Cooper, W.W., and Rhodes, E., "Measuring the Efficiency of Decision Making Units." European Journal of Operational Research 2:6, 1978. See also "Corrections." Ibid. 3:4, 1979.

[10] Huang, Y.G.L., 1990. An application of data envelopment analysis: measuring the relative performance of Florida general hospitals. *Journal of medical systems*, *14*(4), pp.191-196.

[11] Athanassopoulos, A. D., & Shale, E. (1997). Assessing the comparative efficiency of higher education institutions in the UK by means of data envelopment analysis. Education Economics, 5(2), 117–134.

[12] Avkiran, N. K. (2001). Investigating technical and scale efficiencies of Australian universities through data envelopment analysis. Socio-Economic Planning Sciences, 35(1), 57–80.

[13] Johnes, J., 2006. Data envelopment analysis and its application to the measurement of efficiency in higher education. *Economics of education review*, *25*(3), pp.273-288.

[14] Chang, C.W., Wu, K.S., Chang, B.G. and Lou, K.R., 2019. Measuring Technical Efficiency and Returns to Scale in Taiwan's Baking Industry—A Case Study of the 85° C Company. *Sustainability*, *11*(5), p.1268.

[15] Yang, X.L.; Zhang, Y.J.; Wang, L. An Empirical analysis of total factor productivity of the food processing industry in Jilin Province. J. Agrotech. Econ. 2012, 12, 61–67.

[16] Zhang, Z.; Wang, K. Scale competitiveness of food enterprises and TFP growth. Sci. Technol. Ind. 2014, 14, 83–88.

[17] Qiang, F.U.; Fang, J.I. Total factor productivity of food manufacturing industry in China: A DEA-Malmquist index measurement. Revista Facultad Ingeniería U.C.V. 2017, 32, 1–8.

[18] Dimara, E.; Skuras, D.; Tsekouras, K.; Tzelepis, D. Productive efficiency and firm exit in the food sector. Food Policy 2008, 33, 185–196.

[19] Giokas, D.; Eriotis, N.; Dokas, I. Efficiency and productivity of the food and beverage listed firms in the pre-recession and recessionary periods in Greece. Appl. Econ. 2015, 47, 1927–1941.

[20] Rezitis, A.N.; Kalantz, M.A. Investigating technical efficiency and its determinants by data envelopment analysis: An application in the Greek food and beverages manufacturing industry. Agribusiness 2016, 32, 254–271.

[21] Kumar, M.; Basu, P. Perspectives of productivity growth in Indian food industry: A data envelopment analysis. Int. J. Product. Perform. Manag. 2008, 57, 503–522.

[22] Ali, J.; Singh, S.P.; Ekanem, E. Efficiency and productivity changes in the Indian food processing industry: Determinants and policy implications. Int. Food Agribus. Manag. 2009, 12, 43–66.

[23] Kaur, N.; Kaur, K. Efficiency, productivity and profitability changes in the Indian food processing industry: A firm level analysis. Pac. Bus. Rev. Int. 2016, 1, 264–272.

[24] Mathur, R.; RAJU RAMNATH, S. Efficiency in food grains production in India using DEA and SFA. Cent. Eur. Rev. Econ. Manag. 2018, 2, 79–101.

[25] Gregg, D.; Rolfe, J. Identifying sources and trends for productivity growth in a sample of Queensland broad-acre beef enterprises. Anim. Prod. Sci. 2011, 51, 443–453.

[26] Holyk, S. Measuring technical efficiency and returns to scale in Finnish food processing industry. Int. J. Sci. Basic Appl. Res. 2016, 27, 226–238.

[27] Geylani, P.C.; Stefanou, S.E. Productivity growth patterns in U.S. dairy products manufacturing. Appl. Econ. 2011, 43, 3415–3432.

[28] Rodmanee, S.; Huang, W. Efficiency evaluation of food and beverage companies in Thailand: An application of relational two-stage data envelopment analysis. Int. J. Soc. Sci. Humanit. 2013, 3, 202–205.

[29] Kapelko, M.; Oude Lansink, A.; Stefanou, S.E. Analyzing the impact of investment spikes on dynamic productivity growth. Omega 2015, 54, 116–124.

[30] Kapelko, M.; Oude Lansink, A.; Stefanou, S.E. Assessing the impact of changing economic environment on productivity growth: The case of the Spanish dairy processing industry. J. Food Prod. Mark. 2017, 23, 384–397.

[31] Cooper W, Seiford LM, Tone K. Data envelopment analysis: a comprehensive text with models, applications, references and DEA-solver software. New York: Springer; 2007.

[32] Mousavi-Avval SH, Rafiee S, Mohammadi A. Optimization of energy consumption and input costs for apple production in Iran using data envelopment analysis. Energy 2011;36:909–16.

[33] Banker, R.D., A. Charnes and W.W. Cooper (1984), "Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis". Management Science Vol. 30, No. 9, pp. 1078-1092.

[34] Zhou P, Ang BW, Poh KL. A survey of Data Envelopment Analysis in energy and environmental studies. European Journal of Operational Research 2008;189(1):1-18.

[35] Adler N., L. Friedman & Z.S. Stern (2002):"Review of ranking methods in the data envelopment analysis context." European Journal of Operational Research 140(2):249-265.

[36] Sexton TR, Silkman RH, Hogan AJ. Data Envelopment Analysis: critique and extensions. In: Silkman RH, editor. Measuring efficiency: an assessment of Data Envelopment Analysis. San Francisco, CA: Jossey-Bass; 1986. p. 73-105.

APPENDICES

Appendix A: Cross Efficiency Score

Name	DMU01	DMU02	DMU03	DMU04	DMU05	DMU06	DMU07	DMU08	DMU09
DMU01	92.51	100	92.77	88.02	85.3	90.94	100	87.15	89.66
DMU02	91.58	100	93.15	87.33	86.32	100	100	87.06	90.23
DMU03	21.82	100	99.38	88.34	79.03	90.3	100	91.34	99.95
DMU04	36.19	88.69	91.58	89.16	80.62	86.47	100	86.11	91.35
DMU05	89.57	94.83	91.94	87.11	86.9	87.85	100	85.91	89.69
DMU06	89.05	90.41	90.08	87.55	83.97	100	97.49	83.77	87.98
DMU07	87	89.87	88.03	85.55	85.23	100	100	84.32	86.39
DMU08	17.83	100	98.47	86.21	76.19	89.08	100	92.06	100
DMU09	19.86	100	98.9	87.14	77.84	100	100	91.54	100
DMU10	92.51	100	92.77	88.02	85.3	90.94	100	87.15	89.66
DMU11	25.87	100	99.26	87.39	77.89	90.41	94.36	87.33	98.63
DMU12	90.8	92.72	90.25	88.52	84.4	88.1	100	85.5	87.97
DMU13	88.41	91.42	90.28	86.97	86.5	86.31	100	85.26	87.98
DMU14	25.9	100	97.89	88.6	79.63	91.05	100	90.2	97.63
DMU15	17.83	100	98.47	86.21	76.19	89.08	100	92.06	100
DMU16	90.8	92.72	90.25	88.52	84.4	88.1	100	85.5	87.97
DMU17	91.78	100	92.89	87.59	86.32	90.05	100	87.45	89.73
DMU18	89.54	94.96	91.86	87.02	86.78	100	100	85.86	89.66
DMU19	26.24	100	98.59	87.34	79.48	100	97.16	88.62	98.12
DMU20	89.2	91.22	90.38	87.72	85.78	86.73	100	85.1	88.48
DMU21	89.16	93.05	90.65	87.45	86.86	86.21	100	86.26	88.21
DMU22	22.57	100	99.05	88.19	79.28	100	100	91.01	99.54
DMU23	90.8	92.72	90.25	88.52	84.4	88.1	100	85.5	87.97
DMU24	21.82	100	99.38	88.34	79.03	90.3	100	91.34	99.95
DMU25	89.16	93.05	90.65	87.45	86.86	86.21	100	86.26	88.21
DMU26	90.4	92.33	90.11	88.29	84.52	100	100	85.32	87.98
DMU27	89.2	91.22	90.38	87.72	85.78	86.73	100	85.1	88.48
DMU28	24.69	100	98.72	87.58	80.65	89.71	100	90.91	97.96
DMU29	21.82	100	99.38	88.34	79.03	90.3	100	91.34	99.95
DMU30	36.19	88.69	91.58	89.16	80.62	86.47	100	86.11	91.35
DMU31	90.8	92.72	90.25	88.52	84.4	88.1	100	85.5	87.97
DMU32	19.23	100	98.87	86.87	77.65	89.22	100	91.9	100
DMU33	91.59	100	93	87.31	86.29	90.37	100	87.19	89.81
DMU34	88.62	91.94	89.82	87.14	86.53	85.57	100	85.93	87.51
DMU35	88.18	91.46	89.24	86.69	86.12	100	100	85.52	87.12
DMU36	19.25	100	99.04	86.86	77.69	89.26	100	91.91	100

Name	DMU10	DMU11	DMU12	DMU13	DMU14	DMU15	DMU16	DMU17	DMU18
DMU01	88.07	91.93	82.97	80.18	85.19	82.67	87.15	85.42	100
DMU02	87.48	91.98	79.18	79.55	84.64	81.73	86.22	85.63	100
DMU03	79.31	95.53	69.63	75	85.21	89.03	76.96	84.56	100
DMU04	82.15	87.92	89.84	86.89	85.07	82.01	83.81	83.09	100
DMU05	86.66	89.48	81.1	83.17	84.05	79.21	86.06	85.25	100
DMU06	85.65	87.53	86.58	85.2	83.97	78.51	86.84	82.85	100
DMU07	83.77	85.51	84.57	85.29	82.23	76.72	84.84	84.05	97.55
DMU08	75.58	94.6	64.67	71.2	83.28	89.81	72.79	83.76	96.96
DMU09	77.29	95.09	66.5	73.01	84.16	89.12	74.83	84.14	98.58
DMU10	88.07	91.93	82.97	80.18	85.19	82.67	87.15	85.42	100

DMU11	80.95	96.04	66.13	70.77	84.6	87.46	77.78	81.21	100
DMU12	86.91	88.35	90.4	85.73	84.99	80.37	88.04	84.35	100
DMU13	86.67	87.51	86.55	87.22	84.02	78.2	86.88	84.12	100
DMU14	81.18	94.98	73.71	75.86	85.55	88.32	79.25	84.31	100
DMU15	75.58	94.6	64.67	71.2	83.28	89.81	72.79	83.76	96.96
DMU16	86.91	88.35	90.4	85.73	84.99	80.37	88.04	84.35	100
DMU17	87.7	91.68	81	80.57	84.72	81.86	86.59	86.04	100
DMU18	86.31	89.55	80.76	82.93	84	79.25	85.96	85.14	100
DMU19	80.91	95.41	68.03	73.21	84.69	87.03	78.17	82.69	100
DMU20	86.24	87.64	86.7	86.27	84.23	78.58	86.99	84.53	100
DMU21	86.1	87.94	85.28	86.54	83.89	78.61	86.65	85.84	100
Name	DMU10	DMU11	DMU12	DMU13	DMU 14	DMU15	DMU 16	DMU 17	DMU18
DMU22	79.4	95.43	69.58	74.95	85.13	88.65	77.23	84.47	100
DMU23	86.91	88.35	90.4	85.73	84.99	80.37	88.04	84.35	100
DMU24	79.31	95.53	69.63	75	85.21	89.03	76.96	84.56	100
DMU25	86.1	87.94	85.28	86.54	83.89	78.61	86.65	85.84	100
DMU26	86.39	88.17	89.54	85.78	84.78	80	87.76	84.25	100
DMU27	86.24	87.64	86.7	86.27	84.23	78.58	86.99	84.53	100
DMU28	80.21	94.73	69.58	75.94	84.76	87.22	77.93	84.96	100
DMU29	79.31	95.53	69.63	75	85.21	89.03	76.96	84.56	100
DMU30	82.15	87.92	89.84	86.89	85.07	82.01	83.81	83.09	100
DMU31	86.91	88.35	90.4	85.73	84.99	80.37	88.04	84.35	100
DMU32	76.92	94.86	65.98	72.86	83.85	89.11	74.24	84.33	98.15
DMU33	88.06	91.85	80.75	80.31	84.79	81.88	86.58	85.41	100
DMU34	85.56	87.06	86.13	87.06	83.51	78.06	86.41	85.61	99.47
DMU35	84.79	86.67	85.73	86.65	83.15	77.74	85.99	85.18	99.02
DMU36	76.96	94.91	65.84	72.88	83.9	89.14	74.28	84.28	98.26
Name	DMU19	DMU20	DMU21	DMU22	DMU 23	DMU24	DMU 25	DMU 26	DMU27
DMU01	95.03	75.67	70.44	92.76	81.94	89.09	84.94	80.41	84.29
DMU02	95.64	74.59	71.48	92.76	79.68	88.8	85.69	79.34	83.48
DMU03	93.14	59.12	76.99	100	66.41	94.84	82.34	67.7	72.79
DMU04	88.37	91.18	67.42	94.44	91.38	88.45	82.65	86.34	82.73
DMU05	92.9	83.8	71.19	91.74	84.45	87.32	86.03	82.27	85.94
DMU06	89.86	91.32	66.98	90.89	90.45	86.21	83.1	88.35	86.23
DMU07	86.98	89.34	70.19	88.79	88.38	84.24	85.71	85.82	84.21
DMU08	92	50.73	78.12	100	59.99	94.18	81.3	61.71	67.62
DMU09	92.76	54.88	77.44	100	62.99	94.32	82.04	65.12	69.8
DMU10	95.03	75.67	70.44	92.76	81.94	89.09	84.94	80.41	84.29
DMU11	100	57.05	68.08	100	64.78	93.79	78.19	66.31	73.87
DMU12	89.78	89.47	68.41	91.31	91.56	87.16	84.44	87.75	86.96
DMU13	90.73	91.44	70.35	91.01	90.38	86.45	83.88	86	87.27
DMU14	97.92	63.38	70.88	100	71.28	93.51	82.22	70.57	74.96
DMU15	92	50.73	78.12	100	59.99	94.18	81.3	61.71	67.62

DMU16	89.78	89.47	68.41	91.31	91.56	87.16	84.44	87.75	86.96
DMU17	88.96	74.43	76.85	90.86	79.28	89.22	85.91	79.93	84.32
DMU18	92.77	83.37	71.08	91.76	84.15	87.24	86.05	82.94	84.99
DMU19	100	59.87	69.79	100	67.14	93.27	80.2	68.1	73.93
DMU20	89.76	91.55	69.49	91	90.5	86.46	85.34	86.92	87.38
DMU21	77.31	85.55	84.79	87.01	84.43	87.56	86.74	86.25	86.91
DMU22	94.13	59.64	75.71	100	66.89	94.39	82.48	68.47	72.66
DMU23	89.78	89.47	68.41	91.31	91.56	87.16	84.44	87.75	86.96
DMU24	93.14	59.12	76.99	100	66.41	94.84	82.34	67.7	72.79
DMU25	77.31	85.55	84.79	87.01	84.43	87.56	86.74	86.25	86.91
Name	DMU19	DMU20	DMU21	DMU22	DMU 23	DMU24	DMU 25	DMU 26	DMU27
DMU26	89.49	89.89	68.45	91.22	91.36	86.89	84.62	88.57	86.17
DMU27	89.76	91.55	69.49	91	90.5	86.46	85.34	86.92	87.38
DMU28	94.12	62.14	73.24	100	69.01	92.75	83.42	68.99	73.98
DMU29	93.14	59.12	76.99	100	66.41	94.84	82.34	67.7	72.79
DMU30	88.37	91.18	67.42	94.44	91.38	88.45	82.65	86.34	82.73
DMU31	89.78	89.47	68.41	91.31	91.56	87.16	84.44	87.75	86.96
DMU32	90.24	53.6	80.76	99.11	61.69	94.49	82.1	63.89	69.62
DMU33	95.89	75.23	71.51	92.75	80.68	88.94	84.73	79.11	84.2
DMU34	76.24	86.81	84.57	86.4	85.31	86.91	86.66	86.84	86.8
DMU35	80.52	87.97	78.11	87.6	86.81	85.95	86.47	87.54	85.33
DMU36	91.67	54.06	78.2	100	62.29	94.21	82.09	63.92	69.6
Name	DMU28	DMU29	DMU30	DMU31	DMU 32	DMU33	DMU 34	DMU 35	DMU36
DMU01	87.25	88.53	77.69	81.47	85.78	94.43	74.66	71.05	87.13
DMU02	86.7	88.26	76.17	80.11	87.11	94.58	72.82	74.25	88.16
DMU03	92.39	93.51	66.95	68.22	89.35	74.98	58.03	63.38	93.62
DMU04	90	88.65	88.68	85.92	82.19	84.79	79.37	73.85	85.86
DMU05	86.22	87.08	81.78	83.61	86.41	94.14	77.29	82.75	87.61
DMU06	86.84	86.16	86.67	87.67	81.74	91.9	82	100	84.3
DMU07	84.56	84.48	85.34	85.66	84.86	92.67	81.13	83.56	85.26
DMU08	91.36	92.88	60.75	62.31	90.69	70.79	51.31	59.64	94.24
Name	DMU28	DMU29	DMU30	DMU31	DMU 32	DMU33	DMU 34	DMU 35	DMU36
DMU09	91.78	93.08	63.62	65.18	90.2	73.14	54.44	61.78	94.08
DMU10	87.25	88.53	77.69	81.47	85.78	94.43	74.66	71.05	87.13
DMU11	90.65	92.45	63.96	67.24	83.87	77.86	54.65	59.88	90.01
DMU12	87.46	87.14	87.15	88.14	83	93.47	83.11	75.19	84.9
DMU13	86.97	86.54	86.75	87.62	84.84	94.43	83.21	81.23	86.73
DMU14	91.48	92.77	69.62	71.15	87.4	80.64	60.27	64.29	91.44
DMU15	91.36	92.88	60.75	62.31	90.69	70.79	51.31	59.64	94.24
DMU16	87.46	87.14	87.15	88.14	83	93.47	83.11	75.19	84.9
DMU17	86.99	88.11	77.15	80.98	87.36	90.22	76.73	72.14	88.11
DMU18	86.27	87.06	81.37	83.41	86.42	94.08	76.99	81.62	87.62
DMU19	90.74	92.35	65.94	68.67	86.43	79.99	56.76	63.37	91.47
DMU20	86.66	86.51	87.37	87.73	84.22	93.54	82.5	82.23	85.87
DMU21	86.82	86.23	85.4	86.65	86.75	84.23	88.58	77.82	87.3
DMU22	92.09	93.25	67.03	68.51	89.2	76.12	58.04	63.68	93.37
DMU23	87.46	87.14	87.15	88.14	83	93.47	83.11	75.19	84.9
DMU24	92.39	93.51	66.95	68.22	89.35	74.98	58.03	63.38	93.62
DMU25	86.82	86.23	85.4	86.65	86.75	84.23	88.58	77.82	87.3

DMU26	87.36	86.95	87.08	88.08	83.15	93.4	82.97	75.65	85.02
DMU27	86.66	86.51	87.37	87.73	84.22	93.54	82.5	82.23	85.87
DMU28	92.46	90.89	67.4	68.23	89.22	79.98	58.38	63.77	93.48
DMU29	92.39	93.51	66.95	68.22	89.35	74.98	58.03	63.38	93.62
DMU30	90	88.65	88.68	85.92	82.19	84.79	79.37	73.85	85.86
DMU31	87.46	87.14	87.15	88.14	83	93.47	83.11	75.19	84.9
DMU32	91.64	92.94	62.99	64.46	90.86	71.36	54.46	61.49	94.44
DMU33	87.02	88.38	76.75	80.71	86.87	94.94	73.98	73.08	88.13
DMU34	86.44	85.67	86.28	87.15	86.41	83.97	89.57	78.26	86.78
DMU35	86.05	85.32	85.83	86.82	86.07	87.39	86.33	100	86.34
DMU36	92.05	92.59	62.89	64.14	90.57	72.55	53.72	61.13	94.49

Appendix B: Targets

Name	input1 Value	input1 Target	Input1 Gain (%)	input2 Value	input2 Target	Input2 Gain (%)	input3 Value	input3 Target
DMU01	0.85	0.77	-9.22	0.11	0.1	-9.23	0.85	0.79
DMU02	0.87	0.87	0	0.11	0.11	0	0.86	0.86
DMU03	0.89	0.88	-0.62	0.11	0.11	-2.49	0.92	0.87
DMU04	0.88	0.77	-12.54	0.11	0.1	-12.54	0.89	0.78
DMU05	0.96	0.83	-13.14	0.12	0.11	-13.14	0.99	0.85
DMU06	0.91	0.91	0	0.11	0.11	0	0.9	0.9
DMU07	0.98	0.98	0	0.12	0.12	0	0.96	0.96
DMU08	0.94	0.86	-7.94	0.12	0.11	-8.72	0.94	0.86
DMU09	0.9	0.9	0	0.11	0.11	0	0.94	0.94
DMU10	0.88	0.77	-12.81	0.11	0.1	-12.81	0.89	0.79
DMU11	0.94	0.9	-3.96	0.12	0.11	-6.04	0.96	0.89
DMU12	0.91	0.78	-13.76	0.11	0.1	-13.76	0.86	0.78
DMU13	0.95	0.82	-12.84	0.12	0.1	-12.84	0.97	0.82
DMU14	0.87	0.74	-15.32	0.11	0.09	-15.55	0.88	0.75
DMU15	0.93	0.83	-10.19	0.12	0.1	-13.68	0.92	0.82
DMU16	0.92	0.8	-13.23	0.12	0.1	-13.24	0.93	0.81
DMU17	0.93	0.8	-13.96	0.12	0.1	-13.96	0.93	0.8
DMU18	0.88	0.88	0	0.11	0.11	0	0.92	0.92
DMU19	0.96	0.96	0	0.1	0.1	0	0.86	0.86
DMU20	0.85	0.74	-12.74	0.1	0.09	-8.58	0.88	0.77
DMU21	0.81	0.69	-15.21	0.12	0.09	-28.54	0.96	0.69
DMU22	0.96	0.96	0	0.12	0.12	0	0.94	0.94
DMU23	0.92	0.79	-14.33	0.11	0.1	-9.74	0.88	0.81
DMU24	0.87	0.83	-5.16	0.11	0.1	-7.83	0.9	0.81
DMU25	0.99	0.86	-13.26	0.12	0.11	-13.26	0.99	0.84
DMU26	0.91	0.81	-11.75	0.12	0.1	-11.75	0.94	0.83

DMU27	0.85	0.74	-12.75	0.11	0.09	-12.76	0.89	0.77
DMU28	0.94	0.87	-7.73	0.12	0.11	-9.53	0.96	0.86
DMU29	0.94	0.87	-6.49	0.12	0.11	-8.49	0.95	0.86
DMU30	0.96	0.83	-13.44	0.12	0.1	-13.44	0.98	0.84
DMU31	0.93	0.81	-12.44	0.12	0.1	-12.44	0.95	0.84
DMU32	0.98	0.89	-9.14	0.12	0.11	-9.14	0.99	0.89
DMU33	1	0.84	-15.55	0.11	0.11	-5.13	0.9	0.85
DMU34	0.89	0.8	-10.43	0.12	0.1	-17.01	0.97	0.78
DMU35	0.96	0.96	0	1	1	0	1	1
DMU36	0.96	0.9	-5.51	0.12	0.11	-5.78	0.98	0.91
Name	input4 Value	input4 Target	input4 Gain(%)	input5 Value	input5 Target	input5 Gain(%)	input6 Value	input6 Target
DMU01	0.87	0.79	-9.22	0.84	0.76	-9.8	0.86	0.78
DMU02	0.89	0.89	0	0.86	0.86	0	0.88	0.88
DMU03	0.9	0.88	-2.3	0.87	0.85	-2.18	0.9	0.87
DMU04	0.9	0.78	-12.85	0.87	0.76	-13.24	0.89	0.78
DMU05	0.98	0.85	-13.1	0.94	0.82	-13.14	0.97	0.84
DMU06	0.92	0.92	0	0.89	0.89	0	0.92	0.92
DMU07	0.98	0.98	0	0.96	0.96	0	0.99	0.99
DMU08	0.96	0.87	-9.67	0.93	0.84	-9.56	0.95	0.87
DMU09	0.92	0.92	0	0.89	0.89	0	0.92	0.92
DMU10	0.9	0.78	-12.52	0.86	0.75	-11.95	0.89	0.78
DMU11	0.96	0.9	-5.68	0.92	0.87	-5.68	0.95	0.89
DMU12	0.93	0.79	-14.76	0.89	0.77	-13.82	0.92	0.79
DMU13	0.97	0.83	-14.12	0.93	0.81	-12.78	0.96	0.84
DMU14	0.88	0.75	-15.45	0.85	0.72	-15.47	0.88	0.74
DMU15	0.95	0.82	-13.75	0.92	0.79	-14.12	0.94	0.81
DMU16	0.93	0.81	-13.42	0.9	0.78	-13.23	0.93	0.8
DMU17	0.95	0.81	-14.6	0.93	0.79	-15.52	0.94	0.81
DMU18	0.9	0.9	0	0.87	0.87	0	0.89	0.89
DMU19	0.84	0.84	0	0.8	0.8	0	0.83	0.83

DMU20	0.83	0.76	-8.45	0.79	0.73	-8.57	0.82	0.75
DMU21	0.98	0.69	-28.81	0.95	0.67	-29.13	0.98	0.7
DMU22	0.94	0.94	0	0.9	0.9	0	0.93	0.93
DMU23	0.89	0.8	-9.91	0.86	0.77	-9.73	0.88	0.8
DMU24	0.9	0.83	-7.95	0.86	0.8	-7.46	0.89	0.82
DMU25	1	0.86	-13.97	1	0.84	-16.11	1	0.87
DMU26	0.94	0.82	-12.45	0.91	0.79	-13.22	0.92	0.82
DMU27	0.87	0.76	-12.62	0.83	0.73	-12.74	0.86	0.75
DMU28	0.97	0.86	-10.46	0.92	0.84	-9.49	0.96	0.86
DMU29	0.95	0.87	-8.28	0.91	0.84	-7.91	0.95	0.87
DMU30	0.97	0.84	-13.15	0.94	0.81	-13.44	0.97	0.84
DMU31	0.95	0.83	-12.43	0.91	0.8	-12.43	0.94	0.82
DMU32	1	0.9	-10.13	0.98	0.87	-10.41	0.99	0.9
DMU33	0.91	0.86	-5.68	0.87	0.83	-5.06	0.91	0.85
DMU34	0.98	0.8	-18.76	0.94	0.78	-17.03	0.97	0.81
DMU35	0.89	0.89	0	0.9	0.9	0	0.1	0.1
DMU36	0.97	0.91	-6.45	0.94	0.89	-5.73	0.97	0.91
Name	input7 Value	input7 Target	input7 Gain(%)	input8 Value	input8 Target	input8 Gain(%)	input9 Value	input9 Target
DMU01	0.78	0.72	-7.49	0.86	0.77	-9.73	0.87	0.79
DMU02	0.83	0.83	0	0.88	0.88	0	0.9	0.9
DMU03	0.81	0.81	-0.62	0.88	0.87	-1.63	0.92	0.89
DMU04	0.81	0.72	-10.84	0.88	0.77	-13.01	0.9	0.78
DMU05	0.94	0.78	-16.9	0.96	0.83	-13.32	0.99	0.85
DMU06	0.83	0.83	0	0.91	0.91	0	0.11	0.11
DMU07	0.96	0.96	0	0.98	0.98	0	0.98	0.98
DMU08	0.91	0.81	-10.81	0.94	0.86	-8.67	0.96	0.87
DMU09	0.83	0.83	0	0.91	0.91	0	0.93	0.93
DMU10	0.81	0.71	-11.93	0.88	0.77	-12.99	0.93	0.79
DMU11	0.86	0.83	-3.96	0.94	0.89	-5.33	0.96	0.91
DMU12	0.83	0.75	-9.6	0.92	0.79	-14.78	0.93	0.79

DMU13	0.91	0.79	-12.78	0.95	0.83	-12.8	0.97	0.83
DMU14	0.8	0.68	-14.45	0.87	0.73	-15.66	0.89	0.75
DMU15	0.85	0.74	-13.48	0.93	0.8	-13.65	0.95	0.82
DMU16	0.84	0.74	-11.96	0.92	0.79	-13.42	0.94	0.81
DMU17	0.91	0.76	-16.66	0.94	0.8	-14.45	0.96	0.81
DMU18	0.81	0.81	0	0.88	0.88	0	0.9	0.9
DMU19	0.75	0.75	0	0.88	0.88	0	0.87	0.87
DMU20	0.74	0.68	-8.45	0.81	0.74	-8.91	0.83	0.76
DMU21	0.99	0.65	-34.35	0.96	0.69	-28.57	0.99	0.69
DMU22	0.84	0.84	0	0.92	0.92	0	0.94	0.94
DMU23	0.8	0.73	-8.44	0.87	0.79	-9.96	0.89	0.8
DMU24	0.81	0.77	-5.16	0.89	0.82	-8.29	0.91	0.83
DMU25	0.98	0.82	-16.25	0.99	0.86	-13.46	0.99	0.86
DMU26	0.84	0.74	-11.43	0.91	0.81	-11.98	0.87	0.77
DMU27	0.78	0.68	-12.62	0.86	0.74	-13.51	0.93	0.76
DMU28	0.86	0.8	-7.54	0.92	0.85	-7.54	0.96	0.86
DMU29	0.86	0.8	-6.49	0.96	0.86	-10.36	0.96	0.87
DMU30	0.88	0.78	-11.32	0.97	0.83	-14.49	0.98	0.84
DMU31	0.85	0.75	-11.86	0.96	0.81	-15.41	0.95	0.83
DMU32	1	0.85	-15.09	1	0.89	-10.6	1	0.9
DMU33	0.86	0.8	-7.3	0.9	0.85	-6.16	0.91	0.85
DMU34	0.91	0.78	-14.36	0.97	0.8	-17.64	0.99	0.79
DMU35	0.96	0.96	0	1	1	0	0.96	0.96
DMU36	0.93	0.85	-9.03	0.96	0.9	-5.51	0.98	0.92

Name	input10 Value	input10 Target	input10 Gain(%)	output1 Value	output1 Target	output1 Gain(%)	output2 Value	output2 Target	
DMU01	1	0.1	-89.67	0.77	0.77	0	0.79	0.79	0
DMU02	0.13	0.13	0	0.82	0.82	0	1	1	0
DMU03	0.11	0.11	-0.62	0.81	0.81	0	0.91	0.91	0
DMU04	0.11	0.1	-10.84	0.78	0.78	0	0.73	0.74	0.37
DMU05	0.15	0.11	-29.13	0.85	0.85	0	0.8	0.8	0

DMU06	0.12	0.12	0	0.79	0.79	0	0.85	0.85	0
DMU07	0.1	0.1	0	1	1	0	0.82	0.82	0
DMU08	0.1	0.09	-7.94	0.82	0.82	0	0.78	0.78	0
DMU09	0.1	0.1	0	0.81	0.81	0	0.88	0.88	0
DMU10	0.15	0.1	-30.05	0.77	0.77	0	0.79	0.79	0
DMU11	0.13	0.12	-3.96	0.83	0.83	0	0.96	0.96	0
DMU12	0.1	0.09	-13.08	0.8	0.8	0	0.39	0.69	77.48
DMU13	0.11	0.09	-14.81	0.84	0.84	0	0.51	0.72	39.75
DMU14	0.11	0.09	-14.45	0.74	0.74	0	0.72	0.72	0
DMU15	0.1	0.09	-10.19	0.74	0.74	0	0.78	0.78	0
DMU16	0.15	0.1	-31.1	0.81	0.81	0	0.73	0.77	5.16
DMU17	0.11	0.1	-16.17	0.81	0.81	0	0.74	0.74	0
DMU18	0.12	0.12	0	0.89	0.89	0	0.89	0.89	0
DMU19	0.12	0.12	0	0.75	0.75	0	0.97	0.97	0
DMU20	0.11	0.1	-10.34	0.75	0.75	0	0.25	0.75	203.21
DMU21	0.11	0.08	-22.18	0.7	0.7	0	0.63	0.63	0
DMU22	0.1	0.1	0	0.85	0.85	0	0.89	0.89	0
DMU23	0.11	0.1	-9.4	0.8	0.8	0	0.37	0.76	105.05
DMU24	0.11	0.1	-5.16	0.77	0.77	0	0.83	0.83	0
DMU25	0.12	0.09	-22.96	0.87	0.87	0	0.74	0.74	0
DMU26	0.13	0.11	-17.87	0.81	0.81	0	0.48	0.8	68.43
DMU27	0.15	0.1	-32.49	0.75	0.75	0	0.65	0.75	15.03
DMU28	0.11	0.1	-7.54	0.83	0.83	0	0.8	0.8	0
DMU29	0.11	0.1	-6.49	0.82	0.82	0	0.84	0.84	0
DMU30	0.12	0.1	-11.32	0.84	0.84	0	0.4	0.78	96.1
DMU31	0.14	0.11	-22.54	0.83	0.83	0	0.51	0.81	56.83
DMU32	0.11	0.1	-9.14	0.86	0.86	0	0.82	0.82	0
DMU33	0.17	0.1	-38.88	0.86	0.86	0	0.79	0.79	0
DMU34	0.15	0.08	-44.6	0.81	0.81	0	0.36	0.66	84.46
DMU35	0.13	0.13	0	0.77	0.77	0	0.48	0.48	0
DMU36	0.11	0.1	-5.51	0.85	0.85	0	0.86	0.86	0