Integrating Data Envelopment Analysis and Balanced Scorecard for Improving Organizations' Performance Assessment

By

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BCC	Banker, Charnes, and Cooper
BSC	Balanced Scorecard
CCR	Charnes, Cooper, and Rhodes
CRS	Constant Returns to Scale
CSO	Common shares outstanding
DEA	Data Envelopment Analysis
DMUs	Decision Making Units
DRS	Decreasing Returns to Scale
FTSE	Financial Times Stock Exchange
ICB	Industry Classification Benchmark
IFRS	International Financial Reporting Standards
IRS	Increasing Returns to Scale
KPI	key Performance Indicators
NE	Number of employees
NI	Net income
NS	Net Sales
OI	Operating income
PPEM	Profit per employee
R&D	Research and Development
RMS	Relative market share
ROA	Return on Assets
ROE	Return on Equity
RTS	Returns to Scale
TA	Total assets
TAT	Total assets turnover
TC	Total capital
TIA	Total intangible assets
TOE	Total operating expenses
TQM	Total Quality Management
VRS	Variable Returns to Scale

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Declaration

I unequivocally declare that the contents of the present research are of original quality, except in relation to the specific references that are made regarding other scholars. This paper has not been submitted for consideration previously to the current university or to a different one in the past. The entire content of the research is my own personal work, and nothing has been formulated in collaboration with another unless it is clearly specified in the literature.

Abstract

In today's business environment, organizations aim to improve their performance to compete efficiently in a highly competitive global market. Thus, the concept of performance measurement has received significant attention from both academics and practitioners. It has been recognized that performance measurement should take into consideration all aspects of the organization and reflect the organization’s multidimensional nature, including both financial and non-financial factors. Consequently, the Balanced Scorecard (BSC) has been developed to address such a need. Applying the BSC is changing the way top managers administer their organizations and would require them to devote adequate attention to both financial and non-financial aspects, both internally and externally.

Although the BSC has been applied in various areas, there are some pitfalls associated with using it as a tool for evaluating organization performance. The criticisms include first, the fact that BSC lacks a formal implementation methodology; second, adopting a broad set of interrelated indicators may lead to information overload and cause complicated optimization problems; third, BSC does not possess the ability to specify a common scale of measurement; fourth, it does not have a standardized baseline or benchmark required to distinguish between different organization’ performance; and fifth, BSC does not include a mathematical model or a weighting scheme. Recent studies suggest that these limitations can be reduced by combining BSC with other techniques such as Data Envelopment Analysis (DEA), as these two techniques complement each other.

The purpose of this thesis is to develop an improved performance assessment framework by combining BSC and DEA approaches to assess organizations’ performance and then applying this model to assess these organizations’ efficiency levels. The targeted population is all organizations traded on the London Stock Exchange and included in the FTSE All-Share Index, and secondary data are obtained from the financial statements published in the “DataStream” database. The final data set used for the current study consists of 307 organizations covering a period of five years, from 2012 to 2016.

The study also adds to the extant literature by conducting cross-industry level analysis using the combined DEA-BSC model. Hence, it provides managers in different industries with insight to evaluate organizations’ efficiency level to improve their competitive plans and long-term objectives.

The findings of the study suggest that for the seven different industries included in the analysis, the financial perspective of BSC has the greatest effect on the efficiency levels of the

organizations. Additionally, the findings provide an overview of the stability status of each industry by examining the efficiency scores for each industry over the five-year period. The findings provide a broader time horizon and take into account changes that happened in organisations' performance outcomes over time. Furthermore, the results of the analysis categorize organizations in terms of the level of efficiency, identify the possible reasons for such inefficiencies in performance, and provide guidance on potential improvements.

Chapter One: Introduction

1.1 Introduction

The contemporary business environment is characterized by increased competitiveness, the rapid growth of commercial activities, and technological improvement. There is no doubt that it is important for all organizations to establish a performance evaluation system. Hence, this inevitability means that the absence of a performance evaluation system is considered as a defect of the organization strategy (Grafton, Lillis, & Widener, 2010).

Tehrani, Mehragan, and Golkani (2012) stated that evaluating organizational performance is considered a useful phase in accomplishing a self-assessment strategy and therefore enhancing accountability power. In the literature, performance evaluation has been considered as one of the most important techniques in introducing and utilizing the accountability approach. However, there is a need for some indicators through which the organization's performance can be assessed. Performance evaluation indicators are in fact an action guide from 'what it is' towards 'what it should be'. Evaluating the performance of organizations is considered as a guideline that paves the way for future decisions, investment, development, and, most importantly, control and supervision. Hence, this chapter considers the role of the combined DEA-BSC model in enhancing organizations' performance evaluation process. The remaining part of the chapter presents the following: problem statement, research objectives, research questions, and research design.

1.2 Background and Problem Statement

Nowadays, there are several techniques that can be applied in order to assess organizations performance. Neves and Lourenço (2009) suggested that the oldest and the most commonly used technique is financial ratio analysis. However, numerous organizations are highly dependent on financial measures for assessing performance, although depending on financial perspectives to assess performance can be misleading for the decision-makers and can cause the organization to deviate from the correct route. Additionally, Wang, Li, Jan, and Chang (2013) demonstrated that depending on a single indicator in evaluating organization performance provides biased information.

It has been demonstrated that relying on the financial indicators to evaluate performance has many disadvantages; Firstly, financial indicators can be easily manipulated and are short-term oriented, which in turn provides misleading information (Atkinson & Brander Brown, 2001; Johnson & Kaplan, 1987; Phillips, 1999). Secondly, from the competitive environment view, financial indicators do not take into consideration strategic improvement and innovation activities (Ittner & Larcker, 1998; McPhail, Herington, & Guilding, 2008; Sainaghi, 2013). Thirdly, in some industries, especially hotels, financial measures are insufficient for evaluating their performance, as these industries are customer-oriented (Kaplan & Norton, 2001b). Finally, financial indicators do not take into consideration future issues and depend mainly on historical data. Hence, in order to have a holistic view of long-term performance, organizations are motivated to take non-financial perspectives into consideration when assessing their performance (Ramanathan & Ramanathan, 2011).

Consequently, in 1992, Norton and Kaplan introduced the BSC as a performance measurement technique. Kaplan and Norton suggested that four different perspectives should be included when using the BSC, namely the financial perspective, the customer perspective, the internal business perspective, and the learning and growth perspective. The BSC is the most commonly applicable technique which recommends the holistic evaluation of organizational performance using the four perspectives. Hence, managers have argued that the BSC should be applied in order to take into consideration these various measurements. Additionally, the BSC supports organizations' strategies and helps them to achieve their objectives by developing specific indicators to support each goal.

The usefulness of applying the BSC has been addressed by numerous studies (De Geuser, Mooraj, & Oyon, 2009; Khozein, 2012; Lesáková & Dubcová, 2016; Lucianetti, 2010; Senarath & Patabendige, 2015). It has been shown that applying the BSC in organizations has numerous advantages, such as offering criteria related to strategies which can play a motivational and control role, assisting managers to link the control function with the organization's strategies, and associating the financial plans with strategies, as it includes the financial perspective as one of the four dimensions (Michalska, 2005).

In spite of the advantages of applying the BSC to evaluate organizations' performance, several studies (Banker, Chang, & Natarajan, 2005; Eilat, Golany, & Shtub, 2008; Fletcher & Smith, 2004; Lee & Saen, 2012; Rickards, 2003) have criticized the BSC for the following reasons: first, its lack of a formal implementation methodology, mathematical model, or weighting scheme, which in return causes a lack of accountability. Second, adopting a broad set of interrelated indicators may lead to information overload and cause complicated optimization problems. Third, BSC does not possess the ability to specify a common scale of measurement. Fourth, it does not have a standardized baseline or benchmark required to distinguish between different organizations' performance. Finally, BSC does not provide a holistic index to summarize the interaction between different performance indicators.

Consequently, several authors have suggested that the BSC approach needs to be extended, modified, or integrated with another approach. For instance, Basso, Casarin, and Funari (2018) combined the BSC with the DEA technique in order to evaluate the performance of museums in Venice. Similarly, using a sample of UK organizations, the current study applied the combined DES-BSC model to solve some of the pitfalls of the BSC which are; lack of a formal implementation methodology, mathematical model, and a standardized baseline or benchmark.

In the literature, DEA has been defined as a linear programming-based technique for evaluating the performance efficiency level of organizations, which are termed Decision-Making Units (DMUs). Charnes, Cooper, and Rhodes (1978) stated that the main objective of the DEA is to examine how efficiently a DMU utilizes the available inputs to produce a set of outputs. This study assumes that a combined DEA and BSC model can minimize the complexities of the BSC. This integration between the BSC and the DEA represents the main objective of the current study to overcome some of the pitfalls of the BSC approach.

1.3 Research Objectives and Questions

The main objective of this research is to improve the process of evaluation of organizations' performance and examine organizations' efficiency by applying to different industries in the UK and developing a holistic research framework that combines two techniques: DEA and BSC. To achieve the research objectives, the current study applies BSC as a comprehensive framework for determining performance indicators that will be used as input and output while analysing the DEA-BSC model. As well as this main objective, the following four sub-objectives can be identified:

1. Incorporating indicators of the BSC for the input/output variables of DEA;
2. Solving some of the pitfalls of the BSC;
3. Determining efficient and inefficient organizations; and
4. Identifying reasons for inefficiency to assist managers to establish improvement strategies.

Given the nature of the problem in the current study and to achieve the research objectives, two main research questions can be formulated as follows:

1. Can the DEA-BSC model provide inefficient organizations with measurement and direction regarding the gap between their performance and the performance of efficient organizations?

2. How can the DEA-BSC model provide benchmark information to help inefficient organizations to reach efficiency?

In order to be able to answer these two questions, another two sub-questions should be answered; Which organizations are considered efficient and which are inefficient? And What are the reasons for the inefficiency of the organizations?

1.4 Research Contributions

The main research contributions can be identified as follows:

1. Applying a cross-industry analysis in the context of the UK.
2. Contributes to the techniques of performance measurement methods.
3. Provides a comprehensive evaluation of the performance of different industries in the UK, which in return help managers to;
    - Benchmark and determine the competitive position of their organization,
    - Identify reasons for inefficiency and potential improvements.
4. Contributes to the robustness of the applicability of the combined DEA-BSC model.
5. Provides an overview of the stability of the performance of each organization within each industry. This is especially important for policymakers, economists, and managers.

1.5 Research Method

The targeted population of the study is all organizations traded on the London Stock Exchange and included in the FTSE All-Share Index. In order to provide a comprehensive view for the organizations' performance, the time frame for the data collection is five years from 2012 to 2016, which is a similar time period adopted in previous studies (Banker, Chang, Janakiraman, & Konstans, 2004; Chen, Chen, & Peng, 2008; Wang & Chien, 2016; Wang, Li, Jan, & Chang, 2013). The choice of this time frame is informed by a desire to extend current knowledge on combined DEA-BSC model. The organizations have been classified based on the Industry Classification Benchmark (ICB) which is the standard bench mark classification.

The current study includes organizations from various industries, such as: industrials, consumer services, consumer goods, basic materials, healthcare, oil and gas, and technology. Organizations selected in this study are determined based on the following criteria: first, the availability of financial data over five years starting in 2012 and ending in 2016; second, the availability of information about the other three non-financial perspectives of the BSC, which are customers, internal process, and learning and growth perspectives. However, the current study excludes the financial industry, which includes banks, insurance, real estate, and financial services, due to their different nature from other sectors, because in order to apply the DEA appropriately, all included DMUs and data utilized should be homogeneous (Serrano-Cinca et al., 2005). Secondary data were obtained from the "DataStream" database. All the data utilized in the current study are obtained from the financial statements of each organization.

The current research is a descriptive study and is based mainly on secondary data (quantitative), and its results are based on facts or observable phenomena, not assumptions. This affects the selection process of the applicable methodology. The final data set used for the current study consists of 307 organizations covering a period of five years, from 2012 to 2016.

Three DEA models had been applied to achieve the objectives of this study:

1. To measure the overall efficiency, which includes both technical and scale efficiency, Constant Returns to Scale (CRS) was applied;
2. To measure the technical efficiency score, Variable Returns to Scale (VRS) was applied;
3. To measure whether an organization is operating optimally for its size (scale efficiency score), Pure Scale was applied.

Both efficient and inefficient organizations for each industry across these three models are identified and a comparative analysis is performed.

1.6 Research Significance

The current research addressed the issues of organizations' performance evaluation process using different efficiency scores (overall, technical and scale), and the findings of the study provide a distinct policy prescription to improve the performance of organizations in different industries. The most valuable outcomes of the study are the identification of sources of efficiency and the assessment of the amounts of inefficiencies. Nowadays, the focus of public management and policy is to increase the output using the same amount of inputs (resources) or less. Therefore, there was interest in the techniques used for assessing the efficiency of organizations across different industries.

The significance of the research can be outlined as follows:

1. The study determined a peer set of efficient organizations (with the same outputs and input levels), which served as an achievement target for the inefficient organizations.
2. The study provides potential improvements for the inefficient organizations by developing managerial information on the levels of increase in output and decrease in input that could shift an inefficient organization into an efficient one.

3. By applying the super efficiency model, the study ranked efficient organizations as well as inefficient organizations.
4. The current study provides insight into the stability of each of the seven industries included in the analysis by tracking the efficiency scores from 2012 to 2016.
5. The study pinpointed the specific outputs that were causing organizations to be classed as inefficient, so the strategic planners of the organizations should focus on these outputs for potential improvements.

1.7 Research Limitations

The current research compared the performance of organizations with each other, and its results can be used to describe the behaviour of the organizations within each industry throughout the United Kingdom. However, there are a few limitations, as follows:

1. The selection of the variables, whether inputs or outputs, was based on the availability of both financial and nonfinancial data for 307 organizations covering a period of five years, from 2012 to 2016. Although there are other variables that could be included in the analysis, the data was not available to support their inclusion in the study.

2. According to the DEA technique, the efficiency results produced by DEA are mainly based on data collected. This means that any changes made, by adding or removing either inputs or outputs, can influence existing efficiency levels. Adding or removing DMUs can also influence results. In other words, incorrect input or output causes some DMUs to be given higher efficiency standings than they really have.

3. The rule of thumb which states that the minimum number of analysed DMUs = (A+B) ×2, where A = no. of inputs, and B = no. of outputs, resulted in a minimum of 16 DMUs. Consequently, the researcher limits the number of variables used in order to include all the industries. However, the utilities and telecommunications industries will be excluded, as they have limited numbers of organizations: seven and six organizations respectively.

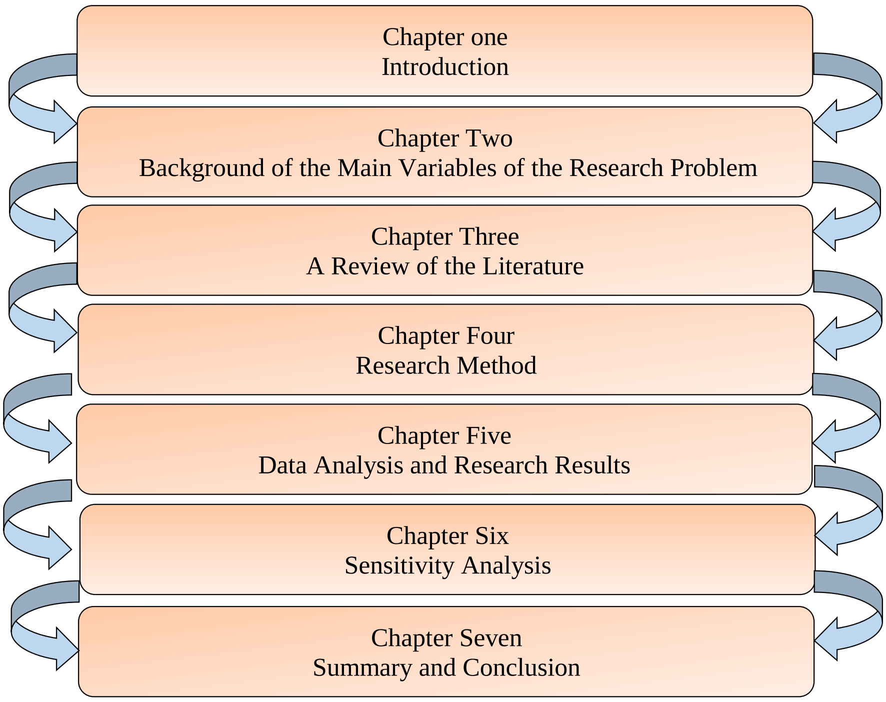
4. DEA provides relative efficiency scores based on the group of organizations included in the analysis: hence, all the efficiency scores provided cannot be considered independent of each other.

1.8 Research Outline

As illustrated in Figure 1.1, the remaining part of the thesis is structured as follows: Chapter two presents a background to the BSC and DEA and their role in evaluating organization performance and gives details about the origin, models, advantages, and disadvantages for each technique. Chapter three provides a review of the literature which is considered as the basis for this thesis. The literature review for the research is classified into three groups, which deal with the main variables of the research. The first group of studies reviewed addresses the relationship between BSC and organization performance; the second group addresses the relationship between DEA and organization performance. The third group sets out the previous research addressing the integration between DEA and BSC and their relations to organizations' performance. The chapter ends with an evaluation of the literature review and an identification of gaps.

Chapter four provides the methodological approach taken in the design and execution of this study. This chapter includes the design of the research, showing the steps followed, which include data collection, the selection of variables, the DEA model that will be used, and finally the building of the combined DEA-BSC model. Chapter five presents the results of applying the combined DEA-BSC to various organizations within seven different industries and identifies the optimal combination of variables. Chapter six shows the sensitivity analysis. Finally, chapter seven outlines the conclusions, implications, limitations of the study, and recommendations for future research.

Figure 1.1 Thesis Structure



Chapter Two: Background to the Main Variables of the Research Problem

2.1 Introduction

Chapter Two of this research provides an overview of the BSC as one of the most commonly used techniques to evaluate organizational performance. The chapter also represents a significant technique to evaluate organizations' efficiency levels, namely the DEA, and then introduces the integration between the two. The chapter starts by examining the evolution, perspectives, generations, and criticism of the BSC. The second section represents a conceptual framework for DEA, which includes definitions, origin, models, advantages and disadvantages of DEA. The final section explains the integration between BSC and DEA and shows the importance of the combined DEA-BSC model for improving organizations' performance assessment.

2.2 Balanced Scorecard (BSC) and Organization Performance

Nowadays, the environment is characterized by increased competitiveness, uncertainty, economic globalization and internationalization of markets, diversity of goods and services provided by organizations to their customers, technological improvement and its impact on shortening the life cycle of products and the presentation of new organizational forms. Consequently, in order to cope with the changes taking place in the surrounding area, considerable changes have to be considered within organizations.Managers of organizations are seeking to make all the procedures related to formulation, planning, implementation and strategy control more flexible and focus on improving their competitive advantages (Burns & Vaivio, 2001; Quesado, Aibar-Guzmán, & Rodrigues, 2016).

Therefore, evaluating performance is an important function for the organization, as it is related to organizational strategy, managerial compensation, and operating performance. If the assessment is not performed in line with the organization's strategy and goals, its reliability will be under question. Roodposhti, Lotfi, and Ghasemi (2010) stated that it is abnormal to assess the performance of a non-profitable organization by considering its revenue; furthermore, assessing commercial banks' performance based on financial vision would be a misleading evaluation and consequently will not provide accurate information for the decision-making process. Neely, Adams, and Kennerley (2002) proposed that performance measurement processes should put forward informed decisions by quantifying the efficiency and effectiveness of past action through collecting and analysing of appropriate data (Farooq & Hussain, 2011; Wang et al., 2013).

Ondoro (2015) categorized performance measures into six groups. The first is effectiveness, which is used to determine the extent to which the provided output complies with required levels. The second is efficiency, which articulates the extent to which the organization provides the desired output levels using the lowest cost for the resources. The third is quality, which describes the extent to which the provided product or service satisfies the needs of the targeted customers. The fourth is timeliness, which is considered as an indicator of accuracy and timely provision of the product or service. Productivity is the fifth group, which refers to the relationship between the value added to the organization by the production process and the capital used and labour cost. The sixth and last group is safety, which reflects the environmental and health issues within the organization.

Although dependence on financial perspectives to assess performance can be misleading for decision-makers and cause the organization to deviate from the correct route, numerous organizations are strongly dependent on financial measures for assessing performance. Additionally, Wang et al. (2013) demonstrated that depending on a single indicator in evaluating organization performance provides biased information and cannot meet the requirements for future development trends.

Since an unbiased performance evaluation system is very important for an organization, and in order to objectively assess organizational performance, the BSC concept is widely applied. In recent years, BSC has been considered as one of the most significant managerial accounting techniques for evaluating organizations' performance. The usefulness of applying the BSC has been proved by a considerable number of articles in academic and professional journals (Cooper, Ezzamel, & Qu, 2017)

The BSC was first introduced by Robert Kaplan and David Norton at Harvard Business School in 1992 as a performance measurement technique. They proposed that the commonly used financial indicators, such as revenues, net profit, and return on assets, did not have the capability to reflect an accurate and comprehensive view of the organization's performance (de Andrade Guerra et al., 2016; Khozein, 2012; Kootanaee, Kootanaee, Hoseinian, & Talari, 2013).

Kaplan and Norton suggested including four different perspectives when using the BSC, namely the financial perspective, the customer perspective; the internal business perspective; and the learning and growth perspective. Hence, managers have argued that in order to take into consideration various measurements, the BSC should be applied, as it provides a comprehensive view of organizations' performance. Additionally, the BSC supports the organization's strategy and helps it to achieve its objectives by developing specific indicators to support each goal.

Dudin and Frolova (2015) stated that the word "balanced" reflects the equal significance of the different measures for developing the organization strategy. Additionally, they mentioned that "in terms of methodology, the BSC is a clear and formalized definition of basic criteria values, characterizing business performance efficiency key performance indicators (KPI). At that, criteria values are itemized depending on the levels of management and business units. Also, all the tasks to be implemented by managers and employees in order to achieve desired results are specified" (p.283).

Consequently, it can be concluded that the BSC concentrates on improving, accomplishing, and aligning with strategies of the organization. In brief, the BSC is considered the most significant and powerful strategic management technique.

2.2.1 Evolution of the Balanced Scorecard

This section discusses how the BSC technique was introduced and how it evolved. The BSC concept was first developed in 1992 and has progressed over time (Barnabè & Busco, 2012; Bible, Kerr, & Zanini, 2006; Eisenberg, 2016; Kaplan, 2012; Kaplan & Norton, 2008; Shukri & Ramli, 2015).

For more than sixty years, the misleading outcomes and disadvantages of traditional performance measurement techniques have been discussed in the literature (Neely, 2007). Since the 1980s, these traditional techniques had been highly criticized by researchers and there has been doubt as to their usefulness to evaluate organizational performance. In this context, several reasons had been raised for not depending on financial indicators to assess organizational performance (Elbanna, Eid, & Kamel, 2015).

Firstly, financial indicators can be easily manipulated and are short-term oriented, which in turn provides misleading information (Atkinson & Brander Brown, 2001; Johnson & Kaplan, 1987; Phillips, 1999). Secondly, from the perspective of the competitive environment, financial indicators do not take into consideration strategic improvement and innovation activities (Ittner & Larcker, 1998; McPhail et al., 2008; Sainaghi, 2013). Thirdly, in some industries, especially hotels, financial measures are insufficient for evaluating performance, as these industries are customer-oriented (Kaplan & Norton, 2001b). Finally, financial indicators do not take into consideration future issues and depend mainly on historical data. Hence, in order to have a holistic view of long-term performance, organizations are motivated to take into consideration the non-financial perspectives when assessing their performance.

To eliminate these pitfalls of relying on financial measures for evaluating performance, researchers have paid close attention to improving performance measurement systems. These systems play a leading role in improving organizational effectiveness by providing managers with the accurate information required for adjusting business operations (Chenhall, 2005; Hall, 2008). Since the mid-1980s, there have been multiple performance measurement systems. For example, Keegan, Eiler, and Jones (1989) introduced the performance measurement matrix; then the SMART pyramid was introduced by Lynch and Cross (1991), and the BSC by Kaplan and Norton (1992). The BSC has been recognized by many researchers as the most influential, multidimensional, and comprehensive performance evaluation technique (Rantanen, Kulmala, Lönnqvist, & Kujansivu, 2007). It had been mentioned by Elbanna et al. (2015) that "the balanced scorecard has been adopted by increasing numbers of organizations, e.g., 57% in the UK, 46% in the US and 26% in Germany and Austria"(p.106).

Madsen and Stenheim (2015) study organized the evolution of the BSCs into two time periods: pre- and post-2000. Firstly, during the pre-2000 period, the main objective of the original BSC introduced by Kaplan and Norton in 1992 was to assist managers in the decision-making process by providing accurate and comprehensive information. Another objective for the primary BSC was to take into consideration both financial and non-financial perspectives. The BSC at this time was named "A dashboard of performance measures".

Subsequently, from 1996, the focus shifted from measuring performance to the link between the BSC perspectives and the strategy of the organization. Furthermore, attention has been paid to the causal relationship between the different perspectives of the BSC (Braam & Nijssen, 2004; Bukh & Malmi, 2005; Kaplan & Norton, 1996; Stemsrudhagen, 2004). Norreklit and Mitchell (2007) expressed this shift as follows: "Instead of using the dashboard as a metaphor, Kaplan and Norton started to use the airplane metaphor, where the managers are seen as pilots using the cockpit's instrument panel to fly the plane to its destination" (p.180).

Secondly, during the post-2000 period, Kaplan and Norton (2001b, 2004) launched the most significant use of the BSC, namely the strategy map. The targets of the strategy map are to clarify and communicate the strategy to all members of the organization and to align different parts of the organization. Subsequently, both of Kaplan and Norton (2005, 2006) studies placed more concentration on the implementation of the strategy and suggested that strategy should be a separately accomplished function in the organization. In brief, Kaplan and Norton’s studies have gradually shifted from a narrow performance measurement technique to a more comprehensive technique taking into consideration the implementation of organization strategy (Kaplan, 2012; Kaplan & Norton, 2008). In spite of the fact that there has been a considerable focus on the BSC as a strategic management technique, most of the organizations still applied the original BSC as a performance measurement technique (Madsen, 2014b; Madsen & Stenheim, 2015).

To sum up, while studying the development stages of the BSC, it was found that the focus differs at each stage, as follows:

- Primarily, the BSC was considered as a performance measurement technique which takes into consideration different financial and non-financial indicators. Hence, it was extended to comprise a management system that helps in linking the strategic and financial objectives of the organization.
- After that, Kaplan and Norton introduced the concept of strategy maps in 2004, which helps in linking the objectives in a causal relationship.
- Meanwhile, the scope of use of the BSC was expanded by providing a sustainable framework for creating value used in different organizations, either non-profit or profit.
- Last but not least, the role of the BSC was extended to integrate different business units of the organization by aligning the organization’s strategy to achieve the whole organization’s goals.

2.2.2 Why are organizations adopting the BSC?

It is important to determine the antecedents that lead to and support the adoption of the BSC, both because it provides valuable information and because it leads to better execution of organisational strategies. Singh and Arora (2018) defined the BSC antecedents as “The factors expected to predict its adoption” (p.876).

Ittner and Larcker (1998) identified three major reasons why organizations are adopting multi-criteria, performance evaluation systems containing both financial and non-financial perspectives:

Firstly, the perceived limitations in traditional performance measurement techniques: it is believed that the traditional accounting measures are focusing on past actions, lack the capability to predict and explain future performance, do not have the ability to cope with new business changes, are too aggregated and summarized, reflect functions rather than cross-functional processes, and provide inaccurate information.

Secondly, competitive pressure: many organizations face changes to the surrounding operating environments, which in turn encourage managers to search for new techniques for evaluating and controlling operational performance. In order to be successful in the new competitive environment and cope with the nature and strength of competition, organizations have to take into consideration the non-financial perspectives.

Thirdly, the growth of other management techniques: other organizations used non-financial measurements due to the widespread adoption of new management techniques, such as total quality management (TQM), which required comprehensive performance measures. It has been argued that effective TQM requires accurate, detailed, and timely process information to be able to determine the sources of shortcomings. Additionally, it has been recognized that TQM emphasizes customers' contentment with the organization's products or services, which in turn leads to greater emphasis on non-financial customer perspectives.

Moreover, Kaplan and Norton (2001a, 2001b) argued that the preceding efforts to include both financial and non-financial measurements in evaluating organization performance, like tableau de board and the experience of Canadian banks, which include environmental measures in their performance evaluation system, were more like ad-hoc attempts that have no systematic approach or guidelines for the selection of those criteria. In contrast, the BSC measures are characterized by being more strategy-linked and translate the organization's mission into operational terms. Additionally, organizations must apply the BSC as they are operating in the information age, which is characterized by increased competitiveness, uncertainty, economic globalization and internationalization of markets, diversity of goods and services provided by organizations to their customers, technological improvement and the increasing importance of knowledge workers and loyal customers.

Another proponent of applying the BSC in organizations is Malmi (2001), whose study addressed the advantages behind adopting the BSC: taking actions to accomplish strategy, dealing with organizational fluctuations; applying for quality programs, coping with managerial changes; and eliminating the traditional financial plans control. Furthermore, Rickards (2003) mentioned that applying the BSC improves the quality of the organization's control system in four ways; first, BSC integrates several management principles in one instrument by choosing suitable variables. Second, BSC includes a broader view than focusing on analysing historical financial data. Third, BSC ensures that top management's strategic goals infiltrate the entire enterprise. Finally, BSC reports information that makes progress toward goal attainment clear.

Using a sample of Scandinavian organizations which had adopted the BSC, Madsen (2013) interviewed 39 managers and found that there were numerous reasons for adopting the BSC. Some managers emphasized enhancing the performance measurement technique, while others focus on organizational politics and changes. Some mentioned broader cultural and social issues. Finally, other managers need to be connected with consultants who indicate that management changes had a significant impact on the decision as to whether or not to apply the BSC (Madsen, 2014a).

These studies argued that the adoption process of the BSC can be explicated by economic and social factors. Madsen and Stenheim (2015) stated that "There is also reason to believe that the motives and rationales might be tangled and interrelated. The available evidence, however, is limited, and it is still not clear which role the supply- and demand-sides play in shaping adoption behaviour in relation to the BSC" (p.28). Additionally, Madsen and Stenheim (2015) summarized the different adoption rates of the BSC that had been mentioned within various studies, as shown in Table 2.1. Recently, Singh and Arora (2018) demonstrated that top management play a leading role in the adoption of the BSC and mentioned that "Top management positively leads to BSC adoption because of its capacity to bringing transparency in organisational working along with the ability to develop innovative corporate culture" (p.886).

Table 2.1: BSC adoption ratio in various countries

Study	**Country**	**Adoption Ratio**
Speckbacher, Bischof, and Pfeiffer (2003)	Germany, Austria, and Switzerland	25 %
Kald and Nilsson (2000)	Nordic countries	27 %
Eriksrud and McKeown (2010)	Norway	30 %
Al Sawalqa, Holloway, and Alam (2011)	Jordan	35 %
Olve (2005)	Sweden	38 %
Anand, Sahay, and Saha (2005)	India	45 %
Anonymous (2001)	UK	57 %
Maisel (2001); Marr and Adams (2004)	USA	60 %
Rigby and Bilodeau (2007)	Worldwide	66 %

Source: Madsen and Stenheim (2015)

2.2.3 The performance effects of using the BSC

Proponents of the BSC concept propose that applying this technique has major consequences in terms of enhancing organizational performance. The literature has shown that applying the BSC in an organization has both direct and indirect effects on its performance (Lesáková & Dubcová, 2016; Senarath & Patabendige, 2015). Furthermore, Singh and Arora (2018) stated that “consequences of adoption vary from no effect to slight indirect effect and of course to clearly evident effect” (p.877).

Regarding to the direct effects of applying the BSC on performance remains in doubt. Numerous studies have identified that applying the BSC in an organization plays a leading role in improving organizational performance by enhancing the effectuation of organization’s strategy and using strategy maps (De Geuser et al., 2009; Khozein, 2012; Lucianetti, 2010). On the contrary, other studies have shown that it is hard to prove the association between application of the BSC and organizational performance because of the various variables that mediate and moderate this relationship (Braam & Nijssen, 2004; Davis & Albright, 2004; De Geuser et al., 2009; Lin, Hu, Tseng, Chiu, & Lin, 2016)

Khozein (2012) showed that there are numerous benefits of implementing the BSC in organizations, as it provides better strategic planning, enhances strategy communication within all levels of the organization, and provides management with accurate information and financial reporting. However, Madsen and Stenheim (2015) stated that to a large extent, the consequences of using the BSC depend mainly on how the concept has been interpreted and implemented. For instance, there will undoubtedly be different effects from implementing the BSC as a performance measurement tool rather than as an organizational strategic management tool (Braam & Nijssen, 2004; Zhijun, Zengbiao, & Zhang, 2014).

Consequently, it is believed that there is a significant strong association between the way of implementing the BSC and the related performance effects (Braam & Nijssen, 2004; Davis & Albright, 2004). It has been noted that adopting the BSC can be a double-edged sword, as applying the BSC can aid the implementation of strategy and hence strengthens the competitive ability of the organization, but its application in cases in which it restricts and is not suitable for implementing the organization’s strategy leads to negative consequences and may diminish performance (Braam & Nijssen, 2004; Davis & Albright, 2004; De Geuser et al., 2009; Lin et al., 2016)

It has been shown that applying strategy maps can enhance organizations’ performance, as organizations that have a comprehensive process associated with the improvement of strategy maps will possess a better fit between the BSC and their strategy. One of the most significant faults in applying the BSC, which may have a negative effect on performance, is the inclusion of excessive and unrelated performance measures (Lucianetti, 2010; Madsen & Stenheim, 2014b).

In the context of the indirect effects of applying the BSC on performance, a number of interview studies with organizations' managers have revealed that managers perceive various advantages of applying the BSC (Madsen & Stenheim, 2014a). For instance, Lesáková and Dubcová (2016) argued that applying the BSC increasing the loyalty of both customers and employees who are targeted for the increase of value. Furthermore, a significant impact of the cause-and-effect relationship within the strategy maps is the increased possibility of achieving the organization's strategic objectives. In turn, this can be beneficial for facilitating strategy explanation and communication within different organizational levels: either top-level managers or employees. Additionally, strategy maps provide guidelines on how the members of the organization should operate in order to achieve the long-term strategic objectives. Therefore, it is anticipated that the application of the BSC, especially the implementation of strategy maps, will be helpful in achieving and enhancing the actual strategy work (Jarzabkowski, Balogun, & Seidl, 2007; Kootanaee et al., 2013; Shen, Chen, & Wang, 2016; Whittington, 2003).

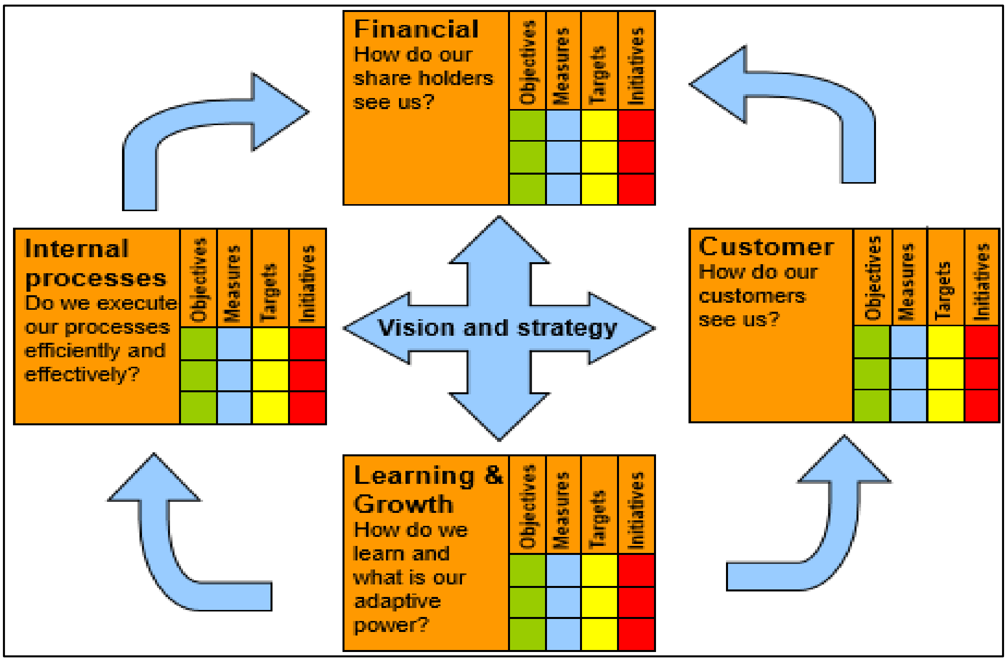
Lesáková and Dubcová (2016) summarized the indirect perceived benefits of applying the BSC as follows: increase understanding of customers' requirements, support decision-makers by providing them with accurate and comprehensive information about performance indicators, eliminate communication difficulties between departments, improve management by providing more effective planning of time and resources, and increase focus on the important tasks for implementing strategy. Furthermore, using a sample of Indian banks, Singh and Arora (2018) showed that adoption of the BSC has positive and significant causal relationships with employees' behaviour, organizational capabilities, and perceived performance.

2.2.4 The Four Perspectives of the Balanced Scorecard

One of the most famous and significant characteristics of the BSC is its perspectives framework. Kaplan and Norton (1992) categorized the BSC into four main perspectives, as shown in Figure 2.1. This figure explains the main question which each perspective seeks to answer, or in other words, it shows the objective of each perspective.

Firstly, the financial perspective measures the final results provided to shareholders, owners, and government and represents the organization's long-term objective (Farooq & Hussain, 2011). Secondly, the customer perspective concentrates on customer requirements, satisfaction, and market share. It is considered as the main perspective of most applied BSC systems. Thirdly, the internal business process perspective directs attention to the performance of the internal business process. It includes the procedures that the organization must develop and align to be successful (Farooq & Hussain, 2011).

Figure 2.1: The Balanced Scorecard Framework



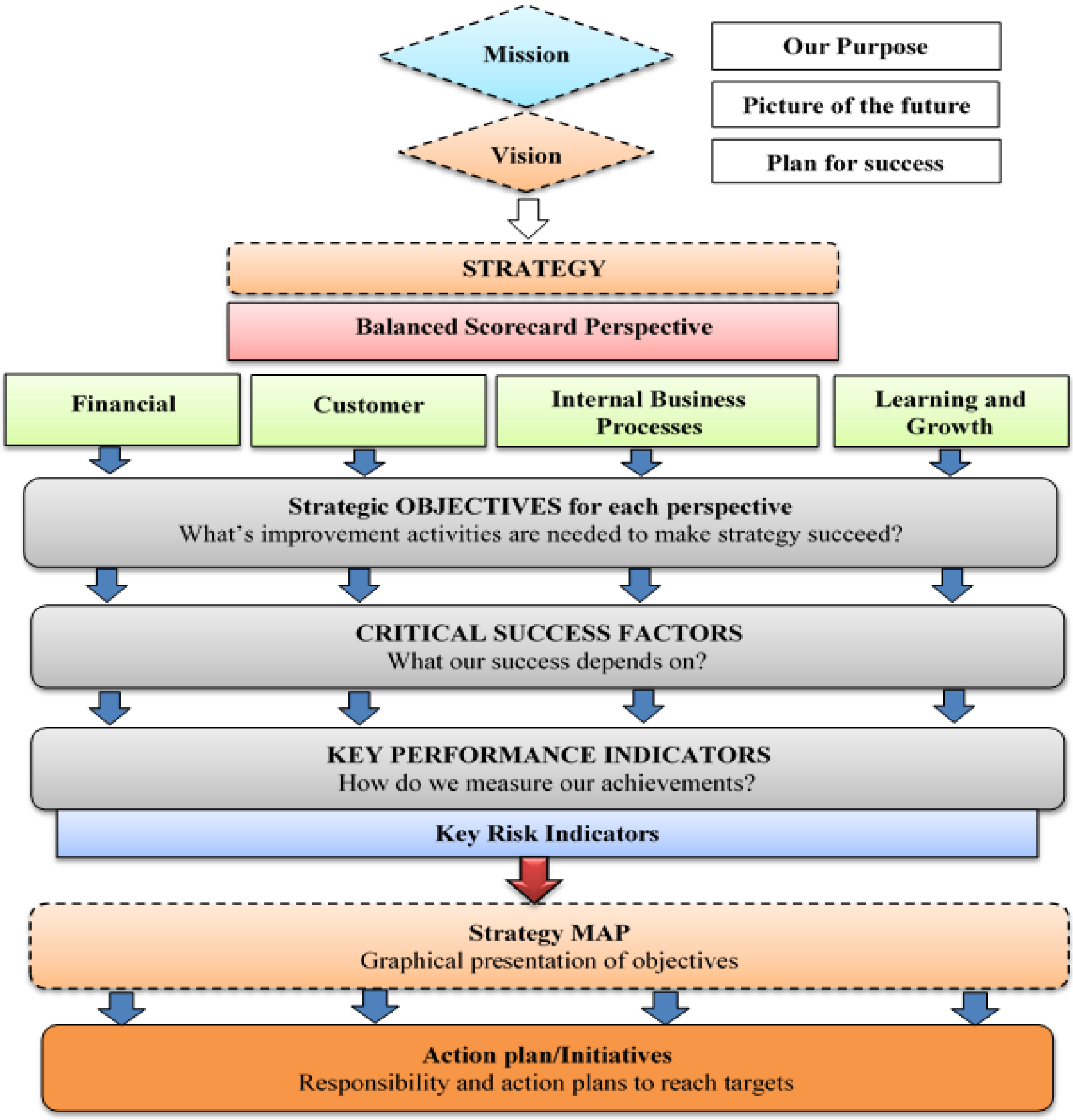
Source: Kaplan and Norton (1996)

Finally, the learning and growth perspective focuses on future success, people in the organization and the organization's infrastructure. Each of these perspectives has certain measures, which has a cause and effect relationship with others. The learning and growth perspective is considered as the backbone to the successful implementation of the BSC. The scope of these perspectives was designed to cover all activities, whether internal or external, current or future (Alharbi, Atkins, Stanier, & Al-Buti, 2016; Anand et al., 2005; Ardabili, 2011; Hoque, 2014; Kaplan & Norton, 1996; Kootanaee et al., 2013; Park & Gagnon, 2006; Rostami, Goudarzi, & Zaj, 2015; Sundin, Granlund, & Brown, 2010; Tabari & Araste, 2008).

Kaplan and Norton (1996) argued that the four financial and nonfinancial perspectives of the BSC should be considered as "a template, not a straightjacket" (p.235). In other words, organizations do not have to be restricted by the four perspectives but can customize the BSC and utilize fewer or more perspectives according to their strategy, objectives, and depending on their industry circumstances. However, those organizations must pay close attention to the causal relationship between the measures of each perspective.

The measures of the BSC must be fully integrated into a chain of causal linkage that reflects the organizational strategic objectives (Kang, Chiang, Huangthanapan, & Downing, 2015; Saraiva & Alves, 2015). As shown in Figure 2.2, each perspective of the BSC has its own goals, indicators, and initiatives.

Figure 2.2: Model of Balanced Scorecard



Source: Kádárová, Durkáčová, and Kalafusová (2014)

2.2.4.1 Financial Perspective: How Do We Look to Our Shareholders?

The main strategic goal of the organization is to improve shareholder wealth by providing superior returns. Although one of the most important advantages of the BSC is that it does not depend only on the financial measures to evaluate performance, financial measures remain the leading focus of most BSC techniques; they determine the long-run goals of the organization.

Kaplan and Norton (1996) pointed out that the financial measures have a dual function: they realize the potential targeted financial performance from the strategy and they present the ultimate goals of the other nonfinancial perspectives of the BSC. While specific measures of performance indicators are selected by the organization based on its strategy, the financial perspective measure relates to profitability. Examples of the most widely used measures are:

- *Operating income*: a measure of profits-revenues less expenses, as reported on the income statement.
- *Return on capital employed:* reflects the organizational investment required to earn profits. This measure provides information about how efficiently the organization employs its investment.
- *Working capital ratios:* these measures concentrate on the capability of the organization to respond to current financial requirements.
- *Sales growth rate by division:* reflects the change in the amount of sales according to each division of the organization.
- *Product line profitability:* indicates the capability of the organization to generate profits from a specific product.

2.2.4.2 Customer Perspective: How Do Customers See Us?

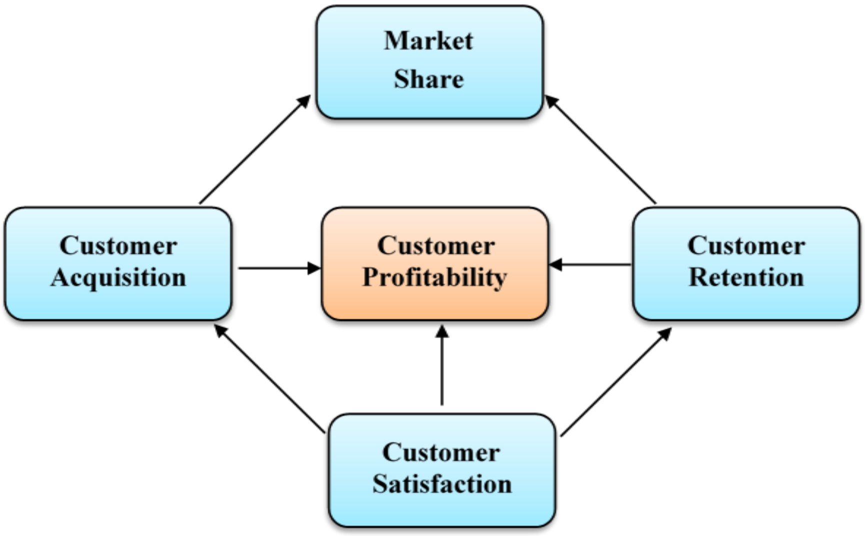
Organizations must shift their concentration to the needs of the customers and supply them with the required products and services that meet their expectations in order to be able to achieve long-run significant financial objectives. From the customer perspective, Kaplan and Norton (1996) showed that managers first have to determine the targeted customers and market segment. Although the core measures are different across various kinds of organizations, they should be tied to the organization's strategy and customized to its targeted customer group. The most commonly applied measures in the customer perspective are the following (Kaplan & Norton, 1998):

- *New customer acquisition:* shows the growth of the organization's customer base. It can be calculated by the ratio of sales to new acquired customers, or by the number of new customers.
- *Customer retention:* reflects customer loyalty. It examines whether or not the organization keeps relations with its customers across time.
- *Customer satisfaction:* indicates how the organization is doing at responding to existing customers' requirements. Measured by using surveys and asking customers about their experience with the organization.
- *Market share:* reflects the ratio of the organization's sales to the overall sales of the market within a specific industry.

- *Customer profitability:* measure the net profit of the desired customer, after having unique expenses because of supporting this customer.

All these measures are interrelated because they affect each other: in other words, customer satisfaction affects the process of acquiring new customers, the loyalty of both new and existing customers, and the profits generated from these customers. Similarly, customer acquisition and customer retention affect the organization's profitability and its market share. Figure 2.3 represents the interrelated relationship between the core measures from the customer perspective.

Figure 2.3: The essential measures of the customer perspective



Source: Kaplan and Norton (1998)

2.2.4.3 Internal Business Process Perspective: What Must We Excel At?

From the internal business process perspective, directors determine the fundamental and important inner procedures that should be accomplished by the organization. This must show the core competencies and important technologies involved in adding value to meet customers' requirements. The internal business process measures should concentrate on the critical procedures that play a leading role in increasing customer satisfaction and attaining the financial objectives of the organization.

As shown in Figure 2.4, each organization has its distinctive combination of processes for adding value for customers and achieving financial outcomes. A guideline for the internal business process is provided by the generic value chain model. The organization can modify it to fit and serve its own goals and measures within its internal business process (Kaplan, Atkinson, & Morris, 1998).

Figure 2.4: The Generic Value Chain Model

Source: Kaplan and Norton (1996)

The most commonly used measures for the internal business process perspective are (Kaplan & Norton, 1996):

- *Quality:* based mainly on the determined quality objectives of the organization. This can be measured by using the number of defective products, scrap, returns, and rework.
- *Cost:* measures include information on the price of a product component and the total cost of producing the product, which includes costs such as ordering, defects, and scheduling.
- *Time:* reflects the interval between the customer placing an order and receiving the required product or service.
- *Throughput:* reflects the duration of the production process for a specific product.

2.2.4.4 Learning and Growth Perspective: Can We Continue to Improve and Create Value?

The determined objectives of the financial, customer and internal business process perspectives showed how the organizations must operate to achieve efficient performance. The objectives in the learning and growth perspective are considered to be the basis for achieving the other BSC objectives. In other words, successful implementation of learning and growth perspective targets guarantees outstanding outcomes in the other BSC perspectives. The primary sources of learning and growth are people, information systems, and organizational alignment (Epstein & Manzoni, 1997; Kaplan & Norton, 1996).

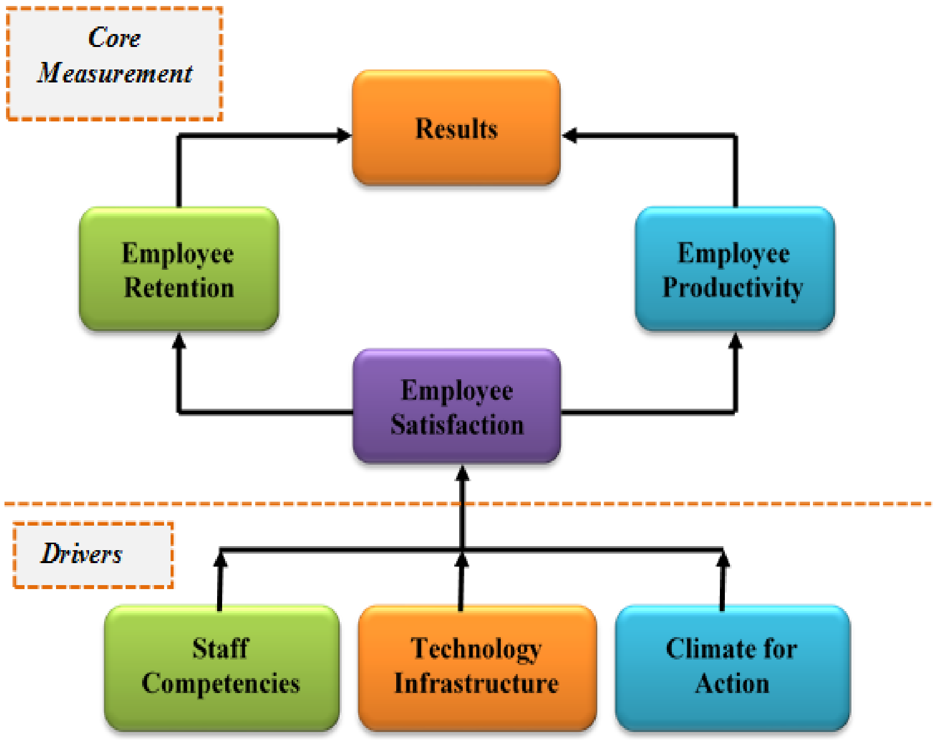
Some organizations faced difficulty with their existing infrastructure in achieving long-term growth in a competitive market. Kaplan and Norton proposed that the BSC helps in determining "gaps" between the organization's existing and desired abilities. Once the gaps have been determined, the organization can find ways to eliminate it, such as the inclusion of tools that are responsible for improving the organization's infrastructure. This perspective can be divided into three principal categories (Figure 2.5):

I. Employee Capabilities

This perspective realizes the importance of a skilled workforce for the success of any organization. The core generic measures include:

- *Employee satisfaction:* usually measured through periodic surveys.
- *Employee retention:* reflects the decrease of intellectual human resources. Commonly measured by the ratio of "staff turnover".
- *Employee productivity:* can be measured using the ratio of revenue to the number of employees.

Figure 2.5: The Learning and Growth Measurement Framework



Source: Kaplan and Norton (1996)

II. Information Systems

In recent competitive circumstances, accurate and timely information is necessary for employees to be able to work effectively. The information should be comprehensive and should reflect customers' requirements, internal process goals, and the financial outcomes of their decisions.

III. Organizational Climate

Kaplan and Norton (1996) stated that “Even skilled employees, provided with superb access to information, will not contribute to organizational success if they are not motivated to act in the best interests of an organization or if they are not given freedom to make decisions and take actions” (p.236).

2.2.5 Balanced Scorecard Generations

Kaplan and Norton’s studies have gradually shifted from the early simplistic performance measurement system, introduced in 1992, through to a more comprehensive system taking into consideration the execution of organizations’ strategy and performance management (Hu, Wildburger, & Strohhecker, 2017; Kádárová et al., 2014; Stefanovska & Soklevski, 2014). The stages of the development of the BSC related to strategy and performance are called “generations”. Table 2.2 provides a comparison between the generations of the BSC.

Table 2.2: BSC generations

Comparison	**Performance Measurement (First Generation)**	**Management System (Second Generation)**	**Strategic Management (Third Generation)**
Generation’s Properties	• Provide a holistic view of organizations’ performance by including financial and non-financial measures. • Determination of specific measures of performance for each business unit and for the whole organization as well.	• In order to achieve the organization’s strategy, there should be a causal relationship between the indicators selected from each perspective of the BSC. • Additionally, there should be a map linked between the strategic objectives of each perspective.	• Linked the four perspectives of the BSC to the organization’s “destination statement”. • The “destination statement” is defined as the descriptive statement to identify where the organization plans to be in the future.
Generation’s Components	• Four perspectives and their indicators:financial, customer, internal process, and the organization’s learning and growth activities.	• The basic component is the strategy map • Shows the strategy map of the organization by connecting the strategic objectives of each perspective. • The causal relationship between the perspectives.	• Includes the components of the previous generations which are; strategic objective, measures and initiatives, strategy map, and perspectives. • The distinctive component of the third generation is the strategic initiatives that help organizations realize its targeted performance.

Generation's Concern	• The focus is to measure the organization's performance.	• Focuses mainly on establishing a strategic linkage model between the measures of the perspectives and showing the causal relationship between the four perspectives. • Furthermore, communicates organizational strategy to employees in the whole organization.	• Focuses on how to connect organizational strategy implementation with the destination statement. • Additionally, improving the strategic management of the organization.
The Reason of Appearance	• To eliminate the disadvantages of using only the financial measures for assessing organizational performance. The BSC solved this problem by taking into consideration both financial and non-financial perspectives.	• The first generation of the BSC cannot link organizational objectives to strategy and does not provide a comprehensive view of the strategy for the employees. • As a result, the second generation extended the original BSC by concentrating on the strategy map concept and the strategic linkage between the four perspectives of the BSC.	• Bessire and Baker (2005) stated that "BSC, as a strategic management system, did not have a descriptive statement that contains a view of organizations in an agreed future or what is called the 'political dimension'" (p.652). • Consequently, the third generation includes the destination statement, as all parties of the organization seek to know the long run objectives of the organization.

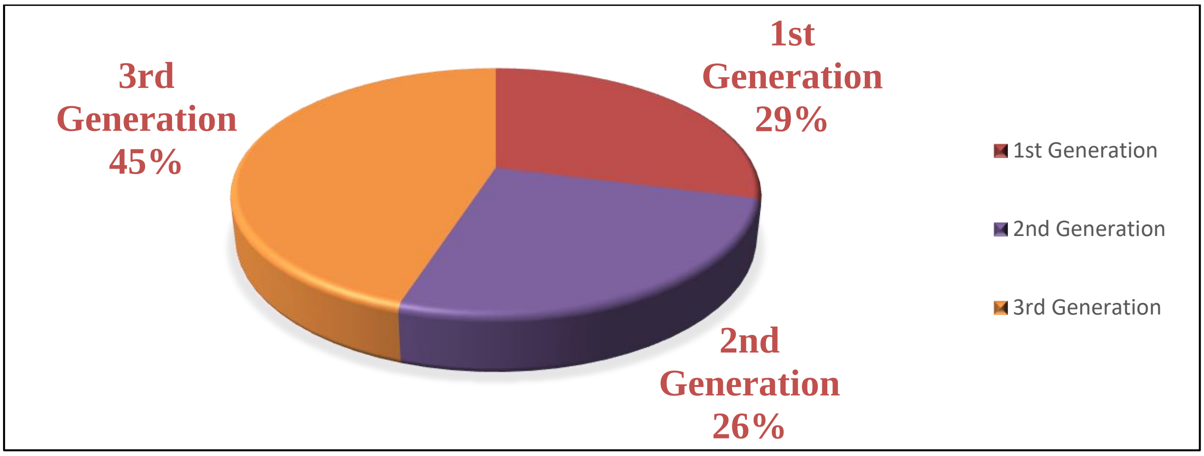
Source: Prepared by the Researcher

The main characteristic that distinguishes the fourth generation of the BSC from the previous generations is that it takes into consideration the impact of external factors. The fourth generation combines the social and environmental perspective with the original perspectives of the BSC. The inclusion of the social and environmental measures will not break down the cause and effect model, as it has been acknowledged that they are considered to be repercussions of the activities and behaviour within the organization. In order to show the comprehensive effect on society or the community, Kádárová et al. (2014) suggested attaching the environmental impact as a separate perspective to the financial perspective and the social impact to the customer perspective.

Studies conducted by Kádárová et al. (2014) and Ivanov and Avasilcăi (2014) showed that the fourth generation of the BSC began with a model about the implementation of the strategy, taking into consideration the uncertainty and risks of the environment. Hence, in order to support the organization's strategy during these circumstances, the BSC utilized external predicting indicators, which guarantee that both managers and employees are involved in the environment where their strategy is accomplished, and in turn, that they will be aware of the potential environmental fluctuations and changes when they are reassessing the strategy with their strategy map.

Kádárová et al. (2014) mentioned that the fourth generation BSC is not commonly used. This was based on a survey conducted by a strategic management consultancy with specific experience in applying the BSC. The survey obtained data on organizations that had applied the BSC since 2009.

Figure 2.6: Types of Balanced Scorecard used



Source: Kádárová et al. (2014)

The findings of the survey showed that in 2013, about two-thirds of the organizations surveyed acknowledged the advantages of applying the BSC. Furthermore, as shown in Figure 2.6, the most commonly utilized BSC generation is the strategic third one (45%), followed by the original generation (29%), and finally the second generation of BSC as a management system (26%). In other words, there is a steady shift towards the application of the BSC as a strategic management system.

2.2.6 Criticism of the Balanced Scorecard

Although many studies have addressed the advantages of applying the BSC, there are opponent studies in the literature showing that organizations have faced difficulties while applying the BSC and that it is considered as a complicated process. Furthermore, there are many negative consequences related to the application of the BSC (Awadallah & Allam, 2015; Madsen & Stenheim, 2014b; Salem, Hasnan, & Osman, 2012). In this section, the researcher will present and discuss the views of some authors who question the merits of the BSC and the ideas of others who suggest that the BSC approach needs extension, modification or integration with another approach. For instance, Basso et al. (2018) combined the BSC with the DEA technique in order to evaluate the performance of museums in Venice

The literature has shown that many organizations have faced various difficulties while applying the BSC (Antonsen, 2010; Kasurinen, 2002; Madsen & Stenheim, 2014b; Modell, 2012; Norreklit, Jacobsen, & Mitchell, 2008; Wickramasinghe, Gooneratne, & Jayakody, 2007). These difficulties ranged from "conceptual and technical problems" to "social and political problems". Whereas the conceptual problems are related to comprehension and explanation of the concept, the technical problems are related to the technical issues required to support the BSC. The other common difficulties are social and political issues. For instance, the application of the BSC may lead to negative behavioural reactions from both employees and managers in the organization, such as opposition and poor participation (Madsen & Stenheim, 2014b).

Atkinson, Balakrishnan, Booth, and Cote (1997) indicated that the BSC is *unable to shed light on supplier requirements and contributions*. It has been addressed that when managers determined the four perspectives of the BSC based on the needs of their organizations, they may neglect their suppliers' requirements and contributions. However, Kaplan and Norton (2001b) have responded to this issue, arguing that "all stakeholders' interests, when they are vital to the success of the business unit's strategy, can be incorporated in a BSC" (p.89).

Furthermore, Norreklit (2000) questioned *the ability of the BSC to be utilized as a strategic management control technique*. Norreklit argued that the control technique is highly top-down, which in turn leads to difficult interactions within the organization. Moreover, the BSC will cause external commitment based on managers' orders and rewards because of its top-down strategy. Hence, Norreklit (2000) stated that "if the external commitment is too high, it encourages employees to concentrate their attention on what is measured" (p.80). However, Kaplan and Norton responded to this point by arguing that for the BSC to be successfully implemented, the employees should be involved in the BSC design phase.

The existence of bias and conflict in performance evaluation is another criticism of the application of the BSC. For instance, Malina and Selto (2001) showed that there are conflict and tension between top and middle management regarding performance evaluation and the use of inappropriate benchmarks for evaluation. Furthermore, Lipe and Salterio (2000) found that while applying the BSC in the organization, the top level managers assess the performance of divisional managers based only on common measures across different business units, and not on the measures that are unique to particular business units.

One of the commonly addressed criticisms of the BSC is the cause-and-effect relationship. Some authors claim that the *cause-and-effect relationships assumption of the BSC falls under suspicion*. Norreklit (2000) argued that the relationship among the BSC perspectives is not a causal relationship, it can be logical or finality relationships. The study mentioned that "A possible counterargument against the criticism of the assumption that a causal relationship is involved is that Kaplan and Norton have a different conception of cause-and-effect relationships. It might be assumed that in fact they intend to refer to finality relationships. A finality relationship occurs when human actions, wishes and views are related to each other" (p.76).

Similarly, Malmi (2001) showed that the supposed cause-and-effect link was weak in his interviewed organizations. Moreover, Salem et al. (2012) pointed out that the causal relationships are unidirectional and too simplistic. To sum up, Perkins, Grey, and Remmers (2014) explained that the criticism of the causal relationship includes three main issues: firstly, the absence of considerations of the time dimension; secondly, the unclear relationship between the perspectives of the BSC; and finally, insufficient recognition of cause-and-effect relationships between various measures. In addition, this causal relationship requires a time lag between cause and effect, which means that BSC does not take into consideration the time dimension. Some effects may be immediate and the others very slow: hence, the time scale is considered to be one of the most critical issues related to the implementation of the BSC.

Brignall (2002) argued that *the BSC did not take into consideration the environmental and social perspectives*, where the cause-and-effect chain is a linear one-way chain starting with the learning and growth perspective and ending with financial outcomes. The researcher thought that the fourth generation of the BSC could solve this point, as it considers environmental and social perspectives.

The effectiveness of the BSC to communicate the strategy to the whole organization is doubted. Applying the BSC compensation system in retail branch banks, Ittner, Larcker, and Meyer (2003) found no evidence that the scorecard approach improved branch managers' understanding of business objectives. Moreover, the study demonstrated statistically that applying the BSC does not provide enough information about progress against the multiple business objectives. In the same context, Malgwi and Dahiru (2014) proposed that poor communication between the top level managers and operational employees leads to strategic problems. Consequently, due to weak communication and inconsistency between the its different levels, the organization's strategic plans may fail.

Additionally, a number of studies (Banker et al., 2005; Eilat et al., 2008; Fletcher & Smith, 2004; Lee, 2012; Rickards, 2003) have criticized the BSC for the following reasons: first, its lack of a formal implementation methodology, which in turn causes a lack of accountability. Second, adopting a broad set of interrelated indicators may lead to information overload and cause complicated optimization problems. Third, the BSC does not possess the ability to specify a common scale of measurement. Fourth, it does not have a standardized baseline or benchmark required to distinguish between different organizations' performance. Fifth, the BSC does not include a mathematical model or a weighting scheme. Finally, it does not provide a holistic index to capture the interactions between different performance indicators. The researcher thus considers that a model that combines the BSC and the DEA can complement the complexities of the BSC. This integration between the BSC and the DEA represents the main objective of the current study, which seeks to overcome many the pitfalls of the BSC.

Lack of the validation: a critical point regarding the BSC mentioned by Malgwi and Dahiru (2014) is that the BSC relies on a small number of measures. It is considered as a double-edged sword, as the advantage of selecting a small number of performance indicators becomes a disadvantage when an incorrect number of measures are selected. This criticism depends on the fact that BSC does not have guidelines for defining the required measures. This calls into doubt the validation of the BSC and increases the likelihood that important measures will be omitted. In brief, the BSC provides a comprehensive frame for the performance perspectives; however, it lacks guidelines for identifying the important required performance measures.

Another criticism of the BSC is that it *concentrates mainly on internal issues*. It thus fails to include information about competitors. Although external change plays a leading role in the application of the BSC, the BSC does not have the ability to evaluate significant fluctuations in the external operational environment. For example, the BSC does not take into consideration the parties of the value chain. It also ignores the role of suppliers and public authorities, which may affect the performance of some organizations (Malgwi & Dahiru, 2014).

Luckily, combining the DEA with the BSC will be helpful with most of the mentioned problems associated with applying the BSC and responding to its most important pitfall, which is the determination of baseline and benchmark figures. Hence, the following part of the current research will provide a clear view of the DEA technique.

2.3 Data Envelopment Analysis (DEA) and Organization Performance

In the last decades, DEA has been increasingly recognized as a significant quantitative analytical technique for assessing organizations' performance. It has been widely implemented in various types of organizations involved in numerous activities in different contexts worldwide. This section represents a conceptual framework for DEA, including definitions, origin, models, strengths, and weaknesses.

2.3.1 Data Envelopment Analysis: Definition

DEA is commonly known as a "data-oriented" technique for assessing the performance of a group of parallel organizations called "Decision Making Units" (DMUs), which consume multiple inputs to produce multiple outputs (Bhatia & Mahendru, 2015; Charles, Kumar, Zegarra, & Avolio, 2011; Chen & Zhu, 2003; Manandhar & Tang, 2002). In the literature, DEA has been defined as a linear programming-based technique for evaluating the performance efficiency level of the organizations, which are termed DMUs. Charnes et al. (1978) stated that the main objective of the DEA is to examine how efficiently a DMU utilizes the obtainable inputs to produce a group of outputs.

The definition of DMUs is comprehensive and flexible: they can encompass manufacturing entities, departments of organizations such as hospitals, schools, universities, banks, electricity stations, airports, railway stations, and health centres (Alamin & Yassin, 2013; Ehsanbakhsh & Izadikhah, 2015; Jayaraman & Srinivasan, 2014; Othman, Mohd-Zamil, Rasid, Vakilbashi, & Mokhber, 2016; Périco, Santana, & Rebelatto, 2016).

Because of the very few assumptions required by the DEA, there is a considerable diversity of applications of DEA worldwide. It has been used to measure the performance of various types of organizations involved in several activities in varying contexts. Furthermore, DEA can be applied in situations where other techniques cannot, as a result of the complicated nature of the other statistical techniques required to address the relationships between the inputs and outputs included in the analysis (Shahroodi & Bahraloloom, 2014).

Cooper, Seiford, Tone, and Zhu (2007) pointed out that applying the DEA provides new recommendations about organizations' performance that had previously been assessed by other techniques. For example, based on profitability measures, the result of some benchmarking studies indicated some profitable organizations to serve as benchmarks; however, after applying DEA, considerable sources of inefficiency were identified. Hence, in many applied studies, DEA has played a leading role in identifying better benchmarks. Consequently, Cooper et al. (2007) assumed that studies examining the efficiency level of different organization forms using other techniques rather than the DEA should be re-evaluated using the DEA, as the effectiveness of these techniques is doubted.

Since the introduction of DEA in 1978, researchers have argued that it is an outstanding and simply applied technique for enhancing organizations' performance assessment. This has been associated with other improvements. For example, Zhu (2003) produced a number of DEA templates that can be utilized in the process of benchmarking and performance assessment. Unlike the traditional forms of statistical regression technique, DEA does not require prior assumptions. This has led to the application of the DEA technique in a range of studies, including efficient frontier estimation, in all sectors, either private or governmental. For example, Takamura and Tone (2003) applied DEA to provide guidelines for government agencies in Tokyo, while Doumpos and Cohen (2014) applied it to assess the efficiency level of local governments in Greece.

Charnes et al. (1978), in their leading primary study, defined DEA as a "mathematical programming model applied to observational data that provides a new way of obtaining empirical estimates of relations such as the production functions and/or efficient production possibility surfaces that are cornerstones of modern economics" (p.441).

Officially, Charnes et al. (1978) stated that "Data Envelopment Analysis is a technique focused on frontiers rather than central tendencies" (p.443). Varying from regression in focusing on the centre of the data, DEA concentrates on uncovering hidden relationships that cannot be determined by other methodologies. For example, DEA takes into consideration the question of what is meant by "efficiency", or in other words, what is the meaning of determining one DMU as the most efficient compared to other DMUs. This is directly achieved by applying the DEA technique without formulation of prior assumptions, which are required by other statistical techniques, such as linear regression techniques.

DEA's merit of avoiding the prior determination of the relative importance of measures (input or output) included in the analysis is credited to the concept of "Relative Efficiency". In order to evaluate the relative efficiency of units including various variables, each variable is given an allocated weight. Hence, Farrell (1957) indicated that "the overall relative efficiency score is a ratio of the weighted sum of the outputs to the weighted sum of the inputs" (p.255). Based on available evidence, a DMU is to be named as fully efficient (100%) only in the case that the performances of other evaluated DMUs indicates that there is no possibility for more improvements of its inputs or outputs without worsening some of its other inputs or outputs.

2.3.2 Theoretical foundations of DEA

In response to the motivation for developing better techniques for evaluating productivity and producing accurate measurements, Farrell (1957) introduced the study which is considered to represent the commencement of DEA. However, the study faced difficulty with integrating the measures of various inputs into a comprehensive scale for evaluating efficiency, such as the separate indicators of labour productivity and capital productivity. In order to adequately resolve this problem, Farrell suggested an activity analysis approach. Furthermore, he shifted his concentration toward the general concept of "efficiency" instead of depending on the narrow concept of "productivity". Hence, the measures presented by Farrell were designed to be appropriate for any productive organization.

Prior to Farrell's study, Charnes, Cooper, and Rhodes (CCR) introduced the primary DEA model. The origin of the CCR model in the early 1970s is credited to the thesis work of Rhodes under the supervision of Cooper at Carnegie Mellon University's School of Public Policy and Management. The main objective of the thesis was to assess an educational scheme specified for black students. The study was applied with the assistance of the Federal government on a sample of US public schools. Although the data obtained for Rhodes's thesis was sufficiently large and the study used multiple input and output variables, the statistical techniques applied provided unsatisfactory results. In order to solve the problem of these misleading results, Rhodes forwarding his attention to the pioneering study of Farrell, which applied the "activity analysis concepts" based on the concept of efficiency rather than productivity to evaluate performance to eliminate what has been believed to be a shortage in the commonly used index number techniques to measure productivity.

A testimony to the usefulness and strengths of using the technique of data envelopment methodology to evaluate performance is its widespread application in different contexts. Emrouznejad, Parker, and Tavares (2008) stated that around 4,000 studies have been published in the context of DEA since the original CCR study in the early 1970s. Researchers in various fields have recognized that the DEA is an outstanding methodology that provides a holistic model for operational processes. Moreover, the advantage of not requiring prior assumptions to be empirically applied has resulted in rapid growth of the DEA technique in various studies, including efficient frontier estimation in both private and public organizations.

Indeed, the frontier concept is more comprehensive than the production function concept. In basic economic terms, the frontier concept simultaneously takes into consideration various production functions for each DMU and provides support to the more efficient units. Recently, DEA has been extended to include a number of alternative approaches for assessing organizations' performance. Charnes et al. (1978) stated that "The original model of Charnes, Cooper, and Rhodes (CCR) had been extended to provide a more profound analysis of both the 'envelopment side' from the primal model and the 'multiplier side' from the dual model of the mathematical duality structure" (p.438).

2.3.3 Basic Definitions related to DEA

This section reviews all the significant concepts that are germane to DEA. This includes definitions to clarify the basic concepts, such as productivity, relative technical efficiency, production function, production frontier, and economic returns to scale.

- ***Productivity***

Prokopenko (1987) defined productivity as the efficient utilization of resources consumed for the provision of various products and services. It introduces the relationship between inputs consumed for the production process and outputs produced. The higher the value of the productivity, the greater the possibility to fulfil more products with the same quantity of resources or to achieve the same quantity of products with a smaller quantity of resources. Due to the inadequacies of the productivity concept in evaluating performance, Farrell (1957) extended this concept to a more comprehensive concept called efficiency, which encompasses both technical efficiency and allocative efficiency (Ab Rahim, 2015; Chen et al., 2008; Sherman & Zhu, 2006).

- ***Efficiency and Efficiency scores***

Generally speaking, in terms of achieving the planned goals, efficiency can be defined as the evaluation of output with regard to input. When applying the DEA technique, each DMU is allocated an efficiency score, ranging from zero percent to one hundred percent. A DMU with an efficiency score of 100% is considered as an efficient unit compared to other units included in the analysis. Any other unit with an efficiency score of less than 100% is considered as an inefficient unit.

- ***Technical Efficiency***

Farrell (1957) suggested the use of two measures for evaluating efficiency. The first of these is technical efficiency, which can be defined as the case under which the organization cannot produce more output for a given amount of available input resources, as well as the situation in which the organization cannot produce the same amount of output with fewer available input resources (Yannick, Hongzhong, & Thierry, 2016).

Technical efficiency can be used to define the amount of waste that can be discarded without worsening either inputs or outputs. Bauer, Berger, Ferrier, and Humphrey (1998) stated that technical efficiency focuses on the physical relationship of the amount of resources (inputs) consumed relative to the number of products or services (outputs) produced without taking into consideration the prices.

Technical efficiency includes both pure technical and scale efficiencies. In other words, technical inefficiency can be a result of pure technical inefficiency, which shows the inefficiency of the organization to achieve the production plan in converting resources to products. Furthermore, technical inefficiency can be a result of scale inefficiency, which represents the deviation of the examined decision-making units from the most productive scale size. Scale efficiency assesses whether an organization is performing at its optimal size. If it is not, then further comparisons of DEA outputs can be applied, using either increasing or decreasing returns to scale.

- ***Allocative Efficiency***

The second measure of Farrell's efficiency measurements is allocative efficiency, also known as price efficiency. Allocative efficiency can be accomplished only when the organization is technically efficient and has the ability to achieve technical efficiency with the minimum total cost of production. Thanassoulis (2003) defined the allocative efficiency of the organization as the relationship between the minimum costs of producing outputs and the cost of the input mix consumed.

Allocative efficiency is applicable based on the availability of information about prices, cost minimization, and profit maximization. Farrell (1957) defined allocative efficiency as "a situation when the price of goods or services is closer to the marginal value of the resources used for production" (p.255). Farrell's two efficiency measures – technical and allocative efficiencies – result in the concept of overall economic efficiency. Given the previous discussion of the two efficiency measures, the current study will examine only technical efficiency. This is informed as a result of data paucity on allocative efficiency.

- ***Production Function***

Farrell (1957) proposed the concept of efficient production function to provide an adequate measure of efficiency. The efficient production function is known as the maximum amount of output that can be produced from a group of inputs. Theoretical and empirical functions are two possible bases upon which to construct an efficient production function.

The theoretical function is not commonly applied, as complex organizations such as those in the manufacturing industry will face various difficulties in developing it. There is a negative relationship between the complexity of the function and the accuracy of results, which means that the accuracy of results will decrease if the complexity of the function increases. The empirical function is based on the observation of inputs and outputs of a group of organizations to assess the efficient production function.

• ***<u>Production Frontier</u>***

The production frontier is a more comprehensive concept than production function. The result of linking Farrell's technical efficiency concept with the production frontier is the DEA technique. The production frontier shows the list of all efficient organizations, which can produce the maximum output amounts for a given input amount.

While organizations that lie on the production frontier are technically efficient, inefficient organizations are those that lie a distance away from the production frontier. For illustration, in Figures 2.7 and 2.8 respectively, the points lying on the frontier represent efficient organizations, while points lying outside the production frontier represent inefficient organizations.

Figure 2.7: CCR Production Frontier

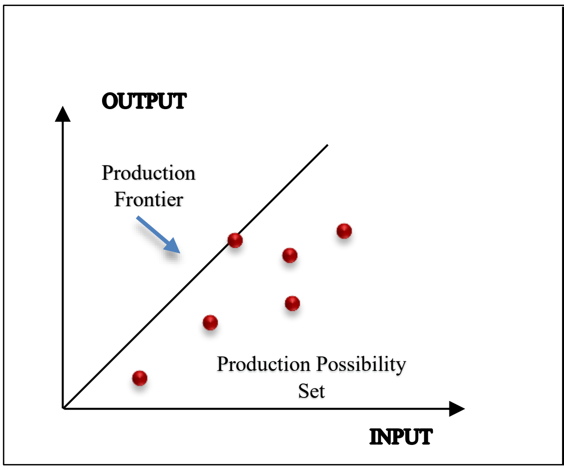
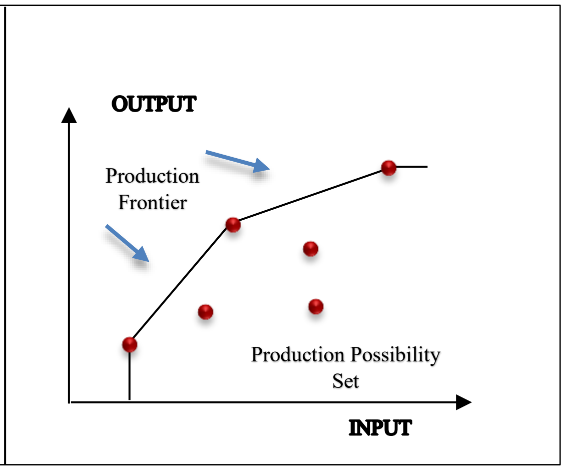


Figure 2.8: BCC Production Frontier



Source: Cooper, Seiford, and Zhu (2004)

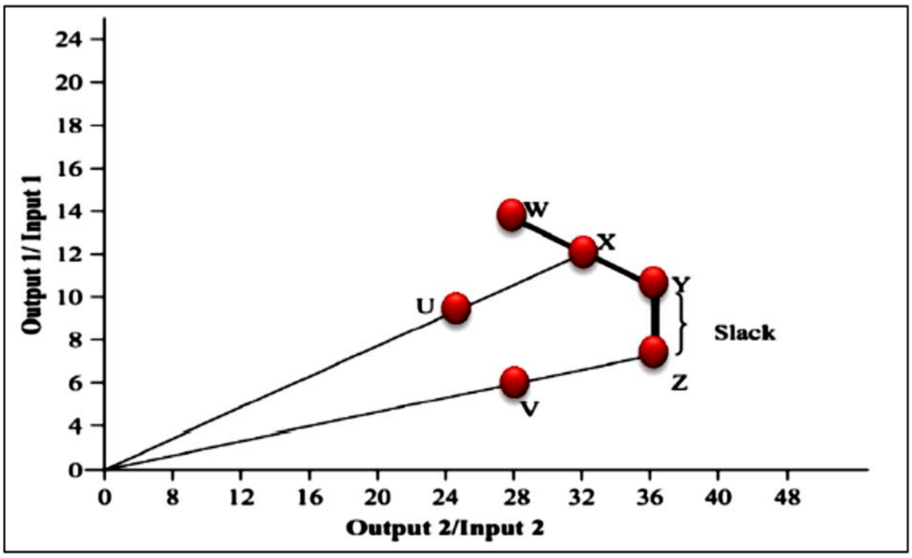
Production frontiers in DEA were developed based on sample data provided by organizations. Hence, they are not ideal frontiers, but are considered as changeable templates. Characteristics of production frontiers can vary based on returns to scale (RTS), which will be discussed in the next section. Figure 2.7, in which the production frontier is linear, represents the original model introduced by CCR that is based on Constant Returns to Scale. The production frontier in Figure 2.8 is formed by the convex hull and represents Banker, Charnes, and Cooper (BCC) model, which is based on Variable Returns to Scale. In both models, the inefficient organization is determined by projecting onto the frontier.

• ***Slacks***

Bürkle (1997) stated that by differentiating between the technical efficiency values of different organizations (DMUs), it is possible to determine organizations which have either overconsumption of resources or underproduction of products or services. In the context of the DEA, these inefficiencies are named “slacks”.

Consequently, slacks are considered as potential areas for improvements. For clarification, Figure 2.9 displays an example from Rickards (2003), showing six organizations (DMUs), each of which produces two outputs by using two inputs. The fifth and sixth DMUs are represented by points Y and Z, respectively. The example will focus on Point Y (DMU 5), located vertically above point Z (DMU 6), on a segment of the envelopment.

Figure 2.9: Slack



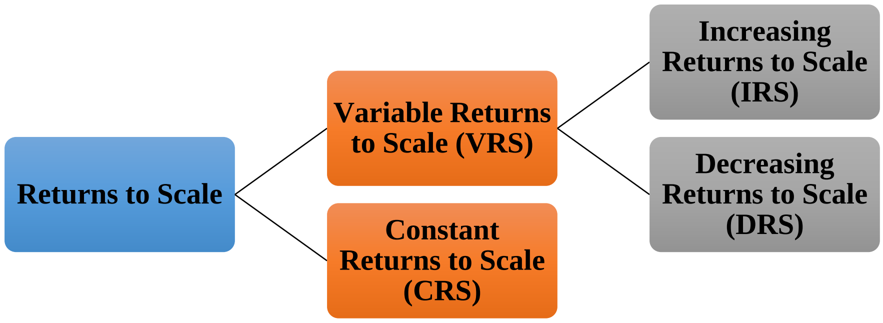
Source: Rickards (2003)

From the output perspective, the difference between the point Y and Z represents the amount of slack or the potential improvements available for DMU 6 at point Z. This means that DMU 6 at point Z can be more efficient and achieve the efficiency level of DMU 5 at point Y by increasing its production of output 1 without any downsizing in its production of output 2. Accordingly, it can be said that DMU 5 (Y) is more efficient than DMU 6 (Z). Hence, slack represents either input wastage or output foregone. Practically, the usefulness of applying potential improvements through slacks should be examined over time.

• ***Returns to Scale***

Returns to scale represent the variation in output scale of production in the long run due to the change in input levels. Figure 2.10 shows the different returns to scale, namely Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS). The original DEA model introduced by CCR relies on the concept of a constant return to scale. Coelli, Rao, O'Donnell, and Battese (2005) stated that “For the proportionate change in all inputs if all outputs vary by the same proportion then the production function exhibits constant returns to scale” (p.17).

Figure 2.10: Types of Returns to Scale



Source: Prepared by the Researcher

For instance, if an organization produces a single output using a single input (e.g. the number of employees), then according to the constant return to scale, the production is expected to double if the number of employees is doubled. Casu and Molyneux (2003) showed that the concept of a constant return to scale is applicable only when the operation of all DMUs is at an optimal scale. On the other side, the DEA model represented BCC relies on the concept of variable returns to scale. According to Coelli et al. (2005), “If for the proportionate changes in all inputs the output results vary by a different proportion, then the production function exhibits Variable Returns to Scale” (p.17).

It has been proved in the literature that the VRS model is the most frequently utilized concept (Alrafadi, Yusuf, & Kamaruddin, 2016). Furthermore, VRS includes Increasing Returns to Scale (IRS) and Decreasing Returns to Scale (DRS). If the outputs changed by a percentage less than the percentage of inputs, then the production function demonstrates DRS, whereas if the outputs changed by a percentage greater than the percentage of inputs, then the production function demonstrates IRS.

2.3.4 DEA and Efficiency Measurement Techniques

There are two main categories of efficiency measurement techniques, namely partial productivity measures and total factor productivity measures. Partial productivity measures applied a ratio between a single input and output. The most commonly utilized partial productivity measure is the average labour productivity, which assesses the output per worker employed. Coelli et al. (2005) introduced other partial productivity measures, namely fuel productivity in power stations and land productivity in agriculture.

The disadvantages of partial productivity measures include the fact that they can introduce misleading information, as they do not take into consideration the impact of other resources on productivity. For instance, enhancing productivity can be a result of either machinery or management changes or labour hours. Additionally, Cooper et al. (2007) showed another deficiency in partial productivity measures, as they do not incorporate the environmental effects on evaluating productivity levels.

On the contrary, to examine the productivity of the organization, total factor productivity measures take into consideration multiple inputs and outputs. Nevertheless, there are difficulties associated with applying total factor productivity measures, namely the determining of inputs and outputs and allocation of weights. There are two approaches for assigning weights, namely fixed weights and variable weights, based on the best set, for each organization to be assessed. DEA applied the concept of the best set of weights to evaluate the efficiency scores. The following are the various efficiency measurement techniques that can be used.

2.3.4.1 Ratio Analysis

The preliminary and commonly used tool to assess the performance of banks is ratio analysis. This is considered to be the most powerful technique for financial analysis. Ratios determine the relationship between two variables and assist in interpreting and simplifying the information of financial statements. Siddiqui (2008) stated that any number of ratios can be used to distinguish between the performance of different banks and their branches over a period of time.

Despite the simplicity of ratio analysis in providing information, however, its complexity increases with the number of ratios. In other words, if the number of required ratios increases, the complexity of ratio analysis will increase as well. The concept of multiple ratios is contradictory and confusing.

Because of this approach, the productivity measure had been limited to single input and output; it cannot be extended to multiple inputs and outputs. Accordingly, ratio analysis is unable to determine inefficient organizations or to predict the actions required to improve organizations' performance (Paradi, Vela, & Yang, 2004).

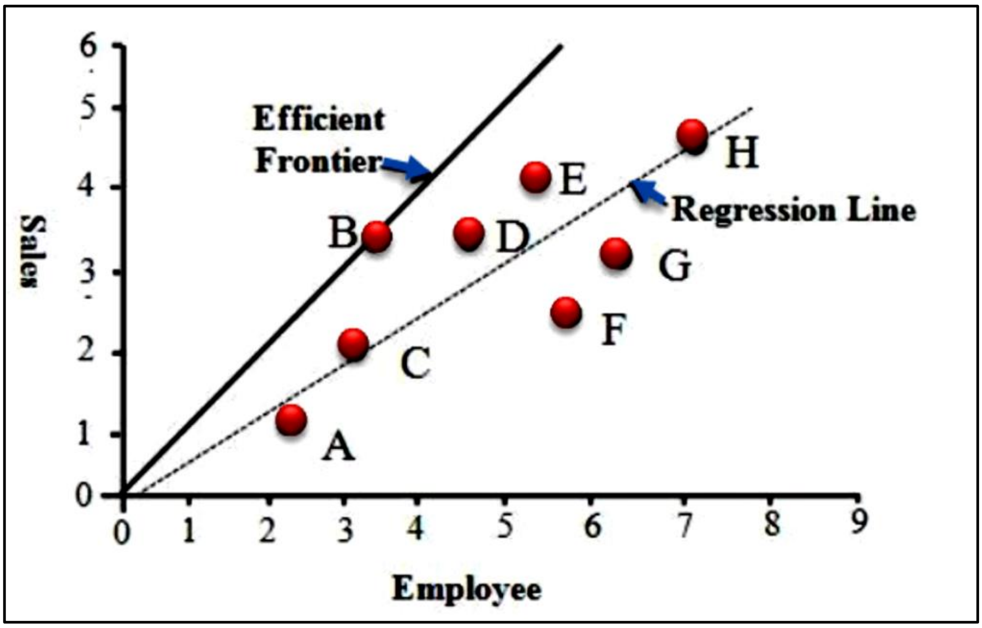
2.3.4.2 Regression Analysis

Regression analysis is defined as a statistical technique that possesses the capability to deal with multiple inputs and outputs to examine the relationship between variables. It recognizes the average behaviour of the variables and determines inefficient units based on their distance from the central tendency. However, regression analysis has some disadvantages: it is unable to determine the potential efficient units and the relationship between them, and it cannot identify the areas of inefficiency of the organization and the improvements required to become efficient.

Thanassoulis (1993) argued that although regression analysis is considered as a difficult process to evaluate performance using multiple inputs and outputs, it has the advantage of being able to cope with random data problems at the input and output levels.

In other respects, compared to regression analysis, frontier analysis has the ability to determine both potentially efficient organizations and the required improvements for inefficient organizations. To clarify, Figure 2.11 distinguishes between regression analysis and frontier analysis.

Figure 2.11: Regression vs. Frontier Analysis



Source: Keshvari and Kuosmanen (2013)

2.3.4.3 Frontier Analysis

Frontier analysis is a contemporary efficiency measurement technique which estimates the efficiency of organizations based on their distance from the frontier formed by efficient organizations. The advantages of applying frontier analysis are that it not only determines the efficiency levels of the organizations, but also determines reasons for the inefficiency associated with them. It provides projection scores, for multiple inputs and outputs considered, to enhance the efficiency level of inefficient organizations. Additionally, it provides the flexibility to determine the efficiency level of organizations based on alternative returns to scale such as constant, increasing, and decreasing.

There are two main groups of frontier efficiency measurement techniques, known as parametric and non-parametric methods. Parametric methods required previous determination of the relationship between inputs and outputs. Non-parametric methods do not require a prior relationship between inputs and outputs. The most commonly used frontier-based method is DEA.

DEA is defined as a non-parametric linear programming methodology to examine the relative technical efficiency of similar organizations, called Decision Making Units (DMUs), using multiple inputs and outputs (Cullinane & Wang, 2006). A DMU can be an organization or a business process which uses resources (inputs) and provides goods or services (outputs). It also can be applied to either a profit or a non-profit organization. Using a linear programming technique, DEA methodology determines the best set of weights for multiple inputs and outputs of each DMU. The efficiency level is calculated as the weighted sums of outputs to inputs. DEA does not require a prior relationship or functional form between inputs and outputs.

2.3.5 Graphical Illustration of DEA

For more clarity and to provide a better view of the application of DEA, this section introduces a simple example to graphically explain the methodology of DEA. The example relies on a single input and a single output. DEA will be applied using a sample of ten hospitals, with the number of nurses as input and the number of patients as output. Consequently, the analysis displays the relationship between patients and nurses. Table 2.3 represents the recorded data for input (nurses) and output (patients), and the relationships between them. It also represents the efficiency scores calculated using the CCR Input Oriented Model of DEA.

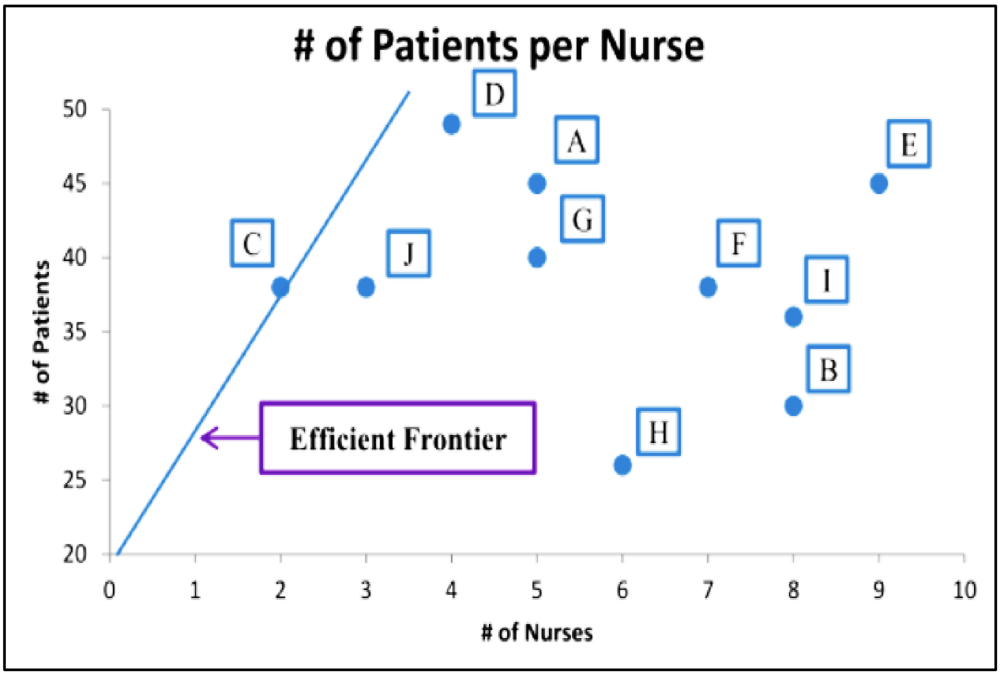
Table 2.3: Single Input and Output

DMU	No. of Nurses	No. of Patients	Patients/Nurse	Efficiency Scores
A	5	40	8.00	0.421
B	8	30	3.75	0.197
C	2	38	19.00	1.000
D	4	49	12.25	0.645
E	9	45	5.00	0.263
F	7	38	5.43	0.286
G	5	45	9.00	0.474
H	6	26	4.33	0.228
I	8	36	4.50	0.237
J	3	38	12.67	0.667

Source: Camanho and Dyson (2005)

Figure 2.12 graphically shows the data recorded in Table 2.3 by plotting the number of nurses on the horizontal axis and the number of patients on the vertical axis. The slope corresponds to the relationship between patients and nurses.

Figure 2.12: Single Input and Single Output



Source: Camanho and Dyson (2005)

The hospital with the highest slope forms the efficient frontier. Whereas the efficient hospitals are those located on the frontier, the inefficient hospitals are those located below the frontier. The efficient frontier envelops all the other points in the plane: hence, this technique obtained the name DEA.

As shown in Figure 2.12, the only efficient hospital is C, and it forms the frontier efficient since it has the highest slope. The other hospitals, such as J, D, A, G, etc., are inefficient, as they are located below the frontier. There are two possibilities for the inefficient hospitals to become efficient or enhance their efficiency level: either by reducing the number of inputs consumed or increasing the number of outputs produced by the hospital. The inefficient hospital *J* can be transformed to an efficient one if it can reduce the number of nurses from 3 to 2 to treat 38 patients or if it can serve 19 more patients with 3 nurses.

2.3.6 Data Envelopment Analysis Models

For the application of the DEA, there are two types of model are the CCR and the BCC. Table 2.4 summarizes an overview of these models and represents their most important characteristics. Table 2.5 provides the notations that will be used in each model.

Table 2.4: Overview of DEA models

Model	Year developed	Orientation of the weighting	Returns to scale
CCR	1978	Input or output	Constant
BCC	1984	Input or output	Variable

Source: Charnes, Cooper, Lewin, and Seiford (1994)

Table 2.5: Notations used in DEA models

$\boldsymbol{DEA}$	Data Envelopment Analysis
$\boldsymbol{DMU}$	Decision Making Unit, which consumes inputs and produces outputs
$\boldsymbol{DMU_0}$	DMU under evaluation or Test DMU
$\boldsymbol{n}$	Total number of DMUs under evaluation
$\boldsymbol{m}$	Total number of input variables
$\boldsymbol{s}$	Total number of output variables
$*$	Optimal solution value
$\boldsymbol{v_i}$	Input multiplier variable of ratio model
$\boldsymbol{u_r}$	Output multiplier variable of ratio model
$\boldsymbol{x_{ji}}$	Represents input variables of ratio model
$\boldsymbol{y_{jr}}$	Represents output variables of ratio model

2.3.6.1 Charnes-Cooper-Rhodes (CCR) Model

The CCR is the first DEA model, and was introduced by Charnes, Cooper, and Rhodes in 1978. The main objective of the CCR model is to determine the efficiency of either input or output. The CCR model provides a measure of overall efficiency. It includes both pure technical efficiency and scale efficiency. Whereas pure technical efficiency examines managerial efficiency, scale efficiency examines whether the organization is operating optimally for its size. The CCR model assumes that an increase in inputs results in the same level of increase in the outputs. For instance, it is assumed that if the inputs are doubled, then the outputs are also expected to double.

CCR is a fractional programming technique which evaluates the relative technical efficiency of the organizations using multiple inputs and outputs (Charnes et al., 1978). "Efficiency is measured as the ratio of the weighted sum of outputs to the weighted sum of inputs" (p.429).

$$Efficiency = \frac{Weighted\ sum\ of\ Outputs}{Weighted\ sum\ of\ Inputs}$$

Consider a dataset of DMUs which use (m) inputs and provide (s) outputs. Input and output data for $\mathrm{DMU_j}$ are represented as, $\mathrm{x_{ji}}(\mathrm{i} = 1, \dots, \mathrm{m})$, and $\mathrm{y_{jr}}(\mathrm{r} = 1, \dots, \mathrm{s})$ respectively, where $(\mathrm{j} = 1, \dots, \mathrm{n})$. The efficiency of each DMU is examined relative to the constraint set of all n DMUs and needs n optimizations to examine the efficiency levels of all the DMUs. DMU under assessment is represented by $\mathrm{DMU_0}$. The following is the fractional programming model based on the definition of efficiency.

$$\boldsymbol{Max} \quad \boldsymbol{Z} = \frac{\sum_{r=1}^{s} \boldsymbol{u_r\ y_{0r}}}{\sum_{i=1}^{m} \boldsymbol{v_i\ x_{0i}}}$$

S. T (1)

$$\frac{\sum_{r=1}^{s} \boldsymbol{u_r\ y_{jr}}}{\sum_{i=1}^{m} \boldsymbol{v_i\ x_{ji}}} \le \boldsymbol{1} \quad \forall\, \boldsymbol{j = 1. \dots . n}$$

$$\boldsymbol{u_r\ .\, v_i \ge 0} \ \ \forall\, \boldsymbol{r = 1. \dots . s.} \quad \boldsymbol{i = 1. \dots . m}$$

In 1978, Charnes converted the Fractional Programming problem model (1) into a linear programming problem model (2). The linear programming problem has to be solved in order to acquire values for input weights, $\mathrm{v_i}(\mathrm{i} = 1, \dots, \mathrm{m})$ and output weights, $\mathrm{u_r}(\mathrm{r} = 1, \dots, \mathrm{s})$ as variables which need to satisfy the constraint set and to optimize the objective function. The constraint set restricts the ratio of the weighted sum of outputs to inputs to not exceed unity for every DMU. Due to the use of multiple weights of input and output, Model (2) is also known as the multiplier approach.

$$\boldsymbol{Max} \quad \boldsymbol{Z} = \sum_{r=1}^{s} \boldsymbol{u_r} \ \boldsymbol{y_{or}}$$

S. T (2)

$$\sum_{i=1}^{m} \boldsymbol{v_i} \ \boldsymbol{x_{0i}} = \boldsymbol{1}$$

$$-\sum_{i=1}^{m} \boldsymbol{v_i} \ \boldsymbol{x_{ji}} + \sum_{r=1}^{s} \boldsymbol{u_r} \ \boldsymbol{y_{jr}} \ \leq \ \boldsymbol{0} \ \forall \ \boldsymbol{j} = \boldsymbol{1}. \dots . \boldsymbol{n}$$

$$\boldsymbol{u_r} \, . \boldsymbol{v_i} \geq \boldsymbol{0} \ \ \forall \ \boldsymbol{r} = \boldsymbol{1}. \dots . \boldsymbol{s}. \quad \boldsymbol{i} = \boldsymbol{1}. \dots . \boldsymbol{m}$$

$$\boldsymbol{Min} \quad \boldsymbol{Z} = \boldsymbol{\theta}$$

S. T (3)

$$\boldsymbol{\theta x_{oi}} - \sum_{j=1}^{n} \ \boldsymbol{x_{ji}} \, \boldsymbol{\lambda_j} \ \geq \ \boldsymbol{0}. \quad \forall \ \boldsymbol{i} = \boldsymbol{1}. \dots . \boldsymbol{m}$$

$$\sum_{j=1}^{n} \ \boldsymbol{y_{jr}} \, \boldsymbol{\lambda_j} \ \geq \ \boldsymbol{y_{or}}. \quad \forall \ \boldsymbol{r} = \boldsymbol{1}. \dots . \boldsymbol{s}$$

$$\boldsymbol{\lambda_j} \ \geq \ \boldsymbol{0} \ \forall \ \boldsymbol{j} = \boldsymbol{1}. \dots . \boldsymbol{n}$$

Model (3) demonstrates the dual linear programming problem of the primal model (2). Primal and Dual are a transposition of each other. This means that if the primal model is a maximization problem then the dual model will be a minimization problem and vice versa. Dual is utilized to determine the amount of inefficiency of DMUs by projecting them onto the efficient frontier. In this situation, the main target of the dual model is to minimize inputs. In order to assess the inefficiency, Model (3) forms an envelope: hence, it is also known as the Envelopment approach.

To sum up, in the case of applying the DEA, the dual model is referred to as the primal model and the primal model is referred to as the dual. The most commonly used model for evaluating the efficiency levels is the dual or the envelopment approach. The literature pointed out the advantage of using the dual model, as it is less computational compared to the primal model. In other words, whereas the dual model contains m + s constraints, the primal model contains n constraints. Moreover, the envelopment model is more significant, as it determines the amount of slack associated with each input and output. Hence, the envelopment model provides recommendations to the management of the organizations for enhancing the efficiency levels.

DEA models can be classified into input- and output-orientated models. The main target of the input-oriented model is to minimize the input used by the DMUs for producing the same targeted amount of output, whilst the main purpose of the output-oriented model is to maximize the outputs produced by the DMUs using the same amount of inputs. Coelli et al. (2005) stated that while input-orientated models addressed the question “By how much can input quantities be proportionally reduced without changing the output quantities produced?”, the output orientated models addressed the question “By how much can output quantities be proportionally expanded without altering the input quantities used?” (p.180). While model (4) represents the formulation of the input-oriented CCR model, model (5) represents the formulation of the output-oriented CCR model (Charnes et al., 1978).

CCR Input-Oriented	CCR Output-Oriented
$\boldsymbol{Min \quad Z = \sum_{i=1}^{m} v_i \ x_{0i}}$ S. T (4) $\boldsymbol{\sum_{r=1}^{s} u_r \ y_{or} = 1}$ $\boldsymbol{-\sum_{i=1}^{m} v_i \ x_{ji} + \sum_{r=1}^{s} u_r \ y_{jr} \ \leq \ 0 \ \forall \ j = 1. \ldots . n}$ $\boldsymbol{u_r . v_i \geq 0}$	$\boldsymbol{Max \quad Z = \sum_{r=1}^{s} u_r \ y_{or}}$ S. T (5) $\boldsymbol{\sum_{i=1}^{m} v_i \ x_{0i} = 1}$ $\boldsymbol{-\sum_{i=1}^{m} v_i \ x_{ji} + \sum_{r=1}^{s} u_r \ y_{jr} \ \leq \ 0 \ \forall \ j = 1. \ldots . n}$ $\boldsymbol{u_r . v_i \geq 0}$

Source: Charnes et al. (1978)

2.3.6.2 Banker-Charnes-Cooper (BCC) Model

In 1984, Banker, Charnes, and Cooper introduced the BCC model as an extension to the CCR. The BCC model proposed variable returns to scale. Banker, Charnes, and Cooper (1984) stated that “The fundamental difference between the CCR and BCC models is u_0 , free variable, in the multiplier approach $\sum \gamma = 1$ and, additional constraint, in the multiplier approach. BCC model production frontier is showed by convex hull of existing DMUs. The frontier has piecewise linear and concave characteristics which lead to variable returns to scale characterizations” (p.1079). Furthermore, Cooper et al. (2007) mentioned that “A free variable u_0 indicates decreasing returns to scale, a negative free variable u_0 indicates increasing returns to scale, and if the free variable u_0 equals to zero then it indicates constant returns to scale” (p.155).

The correlation between the CCR and BCC models is that the BCC production set is a subcategory of the CCR production set. This shows a positive relationship between the two models. For instance, if the DMU has been evaluated using the CCR model and the results show that it is efficient, then if the same DMU is re-evaluated using the BCC model, the results will show that it is efficient, while the converse is not true.

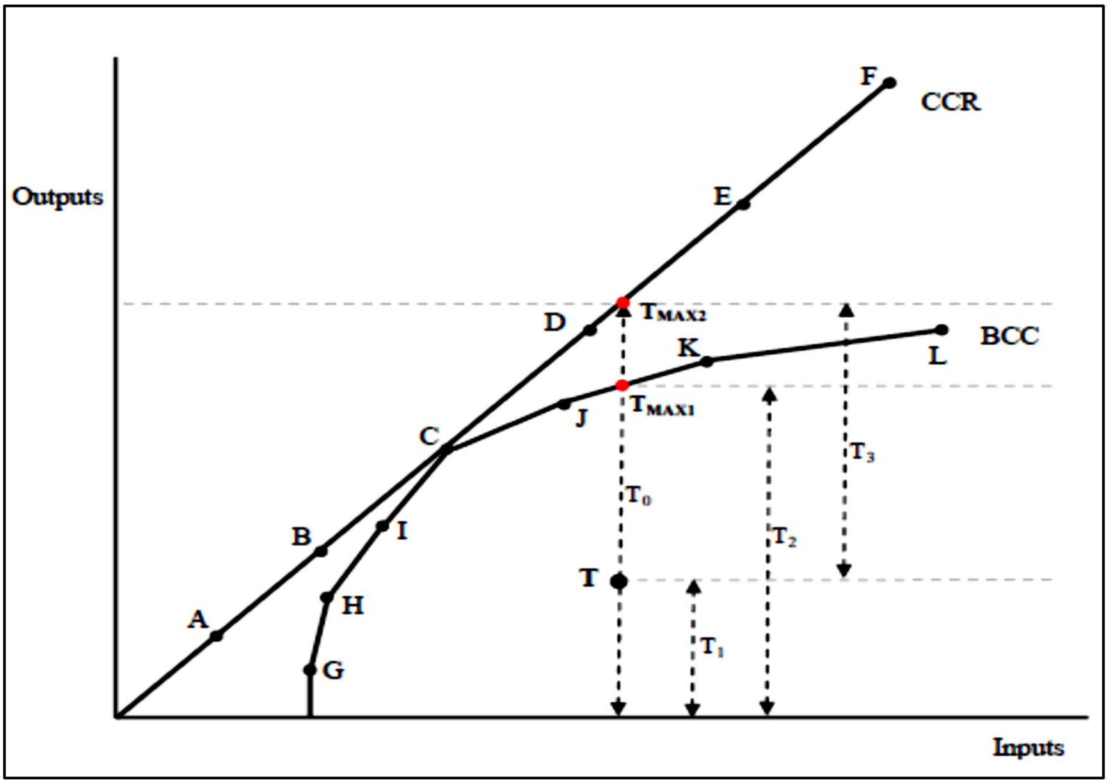
CCR models are selective in allocating efficiency levels; consequently, CCR efficiency levels are always less than or equal to BCC efficiency levels. The CCR model provides a measure of the overall efficiency, which includes pure technical efficiency and scale efficiency. The BCC model represents pure technical efficiency. Sscale efficiency can be measured by dividing the CCR score by the BCC score. For further clarification of the difference between overall efficiency, pure technical efficiency, and scale efficiency, Figure 2.13 shows the difference between the types of efficiency represented by the CCR and BCC models using single output and single input.

Figure 2.13 shows that according to the CCR model, which is based on constant returns to scale, the efficient DMUs are A, B, C, D, E and F. According to the BCC model, which is based on variable returns to scale, the efficient DMUs are G, H, I, C, J, K and L. As the BCC model evaluates pure technical efficiency, scale efficiency can be measured by the ratio of overall efficiency level/pure technical level.

A Constant Return to Scale (RTS) occurs at point C. The Increasing Return to Scale (IRS) is represented by the line that links point K and point C and the Decreasing Return to Scale (DRS) is represented by the line that joins point C to point H. Furthermore, it can be clearly seen in Figure 2.13 that the only organization that is considered commonly efficient in both the CCR and the BCC model is organization C. This reflects the fact that C is the only organization with no “scale effects” in the assessment of its efficiency scores and that it is operating optimally for its size.

Scale efficiency can be represented in the graph by the area representing the difference between the straight line (CCR model) and the curve (BCC model). For instance, for the inefficient organization (T), if it can achieve 100% technical efficiency and reach point TMAX1 and is unable to achieve 100% overall efficiency and reach point TMAX2, this will be due to scale inefficiency, or in other words, due to the large size of the organization.

Figure 2.13: The relationship between CCR and BCC models of the DEA



Source: Wang and Wu (2006)

For the inefficient DMU (T), there are two scenarios. The first, according to the CCR model (overall efficiency), is that to be an efficient unit, the required efficiency score is the distance T1 expressed as a percentage of T0. The second, according to the BCC model (technical efficiency), is that to be an efficient unit, the required efficiency score is the distance T1 expressed as a percentage of T2. Hence, to realize 100% technical efficiency for the DMU (T), it has to reach the point TMAX1. Accordingly, if DMU (T) is unable to realize 100% overall efficiency (TMAX2), the only reason will be scale inefficiencies.

2.3.7 Strengths and Weaknesses of DEA

The strengths and weaknesses of DEA are a direct consequence of how it has been applied. The most common advantage identified by the literature is that the application of the DEA does not require previous assumptions about the production function of the given area. Furthermore, DEA can be used to evaluate a combination of multiple inputs and multiple outputs, which may even be different in nature, such as financial and customer satisfaction indicators. Additionally, DEA can be used for a relatively small sample.

Proponents of the DEA proclaim that compared to other efficiency measurement techniques, DEA is the superior and the most powerful technique (Bazargan & Vasigh, 2003; Cooper et al., 2007; Hsu, Chung, Lee, & Sherman, 2013; Sağlam, 2017), as follows:

- In contrast to the Ratio Analysis technique, which relies on a single input and output, DEA had the ability to deal with multiple inputs and outputs. Hence, it is considered as a Total Factor Productivity.
- Unlike a parametric approach, which requires accurate determination of the relationship between inputs and outputs, DEA is a non-parametric technique that does not require prior definition for the association between inputs and outputs.
- While the regression analysis models mainly focused on the values of the group that has been analysed, the main consideration of the DEA has been to evaluate the level of efficiency and inefficiency associated with each individual unit.
- Unlike fixed weight models, DEA is more useful with flexibility in selecting variable weights to introduce each DMU in its best form.
- DEA can determine the required projections for converting an inefficient organization into an efficient one.
- DEA provides recommendations for the organization's management about the benchmarks that can be used.

Additionally, Sağlam (2017) mentioned the following advantages of applying the DEA: it is able to consider multiple evaluation measures, provide benchmark performance, discriminate adequately between the performances of different organizations, evaluate performance without the need for human judgment in determining the relative importance of each measure, provide potential improvements and determine the practice modifications required to achieve the targeted performance, and identify and penalize compensatory behaviour (high performance in one or more measures compensating for low performance on the others).

Although there are many advantages of applying DEA in various contexts of managing and evaluating performance in accounting, DEA nevertheless possesses a number of pitfalls (Bhat, Verma, & Reuben, 2001; Coelli et al., 2005; Ramanathan & Ramanathan, 2011; Yannick et al., 2016). DEA is only able to evaluate relative technical efficiency: it cannot evaluate absolute efficiency. This shows that 100% technically efficient organizations are the best among the selected sample; however, they may not be 100% absolute efficient. Moreover, DEA has other disadvantages, as follows:

- The quality of the data and outliers present in the data strongly affect the application of the DEA, as it is a frontier technique and the data provided play a leading role in the estimation of the frontier.
- The efficiency results produced by DEA are mainly based on the data collected. This means that any changes by adding or removing either inputs or outputs can influence existing efficiency levels. Adding or removing DMUs can also influence results.
- For the DEA to be applicable, there can be no missing data. In other words, for each DMU, the inputs and outputs included in the analyses should be measurable.
- It is difficult to examine statistical hypotheses, as the DEA is a non-parametric technique.
- As the DEA is considered as an extreme point technique, considerable problems can occur due to measurement error.

2.4 Integrating Data Envelopment Analysis and Balanced Scorecard

Nowadays, the business environment, which is characterised by increased competitiveness, globalization, and diminished economic boundaries between countries, has forced organizations to serve stakeholders' benefits. Hence, to meet the expectations of stakeholders (shareholders, customers, employees, and society), organizations have to use innovative management systems. Furthermore, to cope with the rapid changes in the world and economic progression, organizations must identify the importance of evaluating performance and examine their efficiency levels in order to possess the ability to modify any existing shortages (Alvandi & AzamMasoumi, 2012).

The advantages of performance evaluation have been recognized in the literature as enhancing competitiveness between organizations within various industries, increasing the ability of the organizations to determine current pitfalls, providing organizations with insights required to develop and progress, and providing stakeholders with accurate and appropriate information. Accordingly, most of the managers focused on the techniques used to evaluate performance. Aryanezhad, Najafi, and Bakhshi (2011) stated that the evaluation process includes various criteria, such as the association between the organization's mission and objectives, the potential commercial spread and success, and rewards.

In order to be able to measure the criteria in a qualitative manner, accurate and detailed information is required. However, performance transactions in a dynamic environment cause difficulties with obtaining the required information, which in return leads to misleading opinions and judgments. Eilat et al. (2008) proposed that in a case where evaluating the qualitative of criteria is difficult, then using quantitative indices can solve the problem: for instance, using return on investment rate as an indicator or measure of the market and customer's satisfaction (Papalexandris, Ioannou, Prastacos, & Soderquist, 2005).

Consequently, in 1992, Norton and Kaplan introduced the BSC as a performance measurement technique. Then, in 1996, it was evolved into a strategic technique. The BSC includes qualitative criteria and is considered as a management innovation. It combines both financial and nonfinancial criteria. Additionally, it concentrates on both short- and long-term goals of the organization. The BSC has been utilized by various organizations as a tool for explaining perspectives and strategies, linking strategic objectives and criteria, and enhancing strategic feedback (Alvandi & AzamMasoumi, 2012; Eilat et al., 2008).

The usefulness and advantages of applying the BSC have been addressed in numerous studies (De Geuser et al., 2009; Khozein, 2012; Lesáková & Dubcová, 2016; Lucianetti, 2010; Senarath & Patabendige, 2015). It has been showed that applying the BSC in organizations has numerous advantages, such as offering criteria related to strategies which can playing a motivational and control role, assisting managers to link between the control function and the organization's strategies, and associating the financial plans with strategies, as it includes the financial perspective as one of the four dimensions (Michalska, 2005).

Despite all these advantages, there is a significant obstacle in applying the BSC, which is the absence of a baseline, standards, and a specific model to assess organizations' performance. Aryanezhad et al. (2011) mentioned that evaluating performance without a baseline and standard is impossible and provides misleading information. Hence, due to the difficulties faced by organizations in applying the BSC, the current study proposed that it be combined with DEA.

As the DEA relies on relative efficiency analysis, organizations are evaluated by comparing with each other: consequently, there is no need to determine standards and baseline. In other words, this means that the integration between DEA and BSC helps in solving one of the difficulties related to applying the BSC (Kádárová, Mihok, & Turisová, 2013; Tan, Zhang, & Khodaverdi, 2017)

In order to organize the relationship between DEA and BSC, the leading characteristics of both techniques should be compared. Hence, the main characteristics are summarized in Table 2.6. The current study emphasizes that the combination of DEA and BSC models plays a leading role in enhancing the capabilities of both models and diminishing the disadvantages of each. Figure 2.13 shows how DEA and BSC can be combined.

Table 2.6: Comparison of the main characteristics of DEA and BSC

Comparison context	BSC	DEA
Differentiation method	Comparison with an ideal virtual unit	Compare based on the relative efficiency of a group of DMUs
Main Objective	Self-assessment	Efficiency benchmarking
View	Financial/nonfinancial	Input/output
Mathematical equations	Weak	Strong
Uses	Performance evaluation	Technical efficiency
The accuracy of evaluation	Unclear	High
Providing enhancement	Weak	High
Ranking	Does not provide	Provide ranking for units
Qualitative	Yes	Yes
Quantitative	Yes	Yes
Align to strategy	Support	Does not support
Future view	Provide recommendations	Provide recommendations
Benchmarking	No	Yes
Managerial insights	Linking strategy into tactics	Resource allocation
Main approach	Conceptual framework	Linear programming

Source: Aryanezhad et al. (2011)

Table 2.6 shows the following:

1. Whereas DEA has input and output, BSC has financial and nonfinancial perspectives.

2. BSC focuses on the organization strategy; however, the DEA technique does not take into consideration the strategy of the organization.

3. The results provided by the DEA can be easily analysed; however, it is not easy to analyse the performance index provided by the BSC.

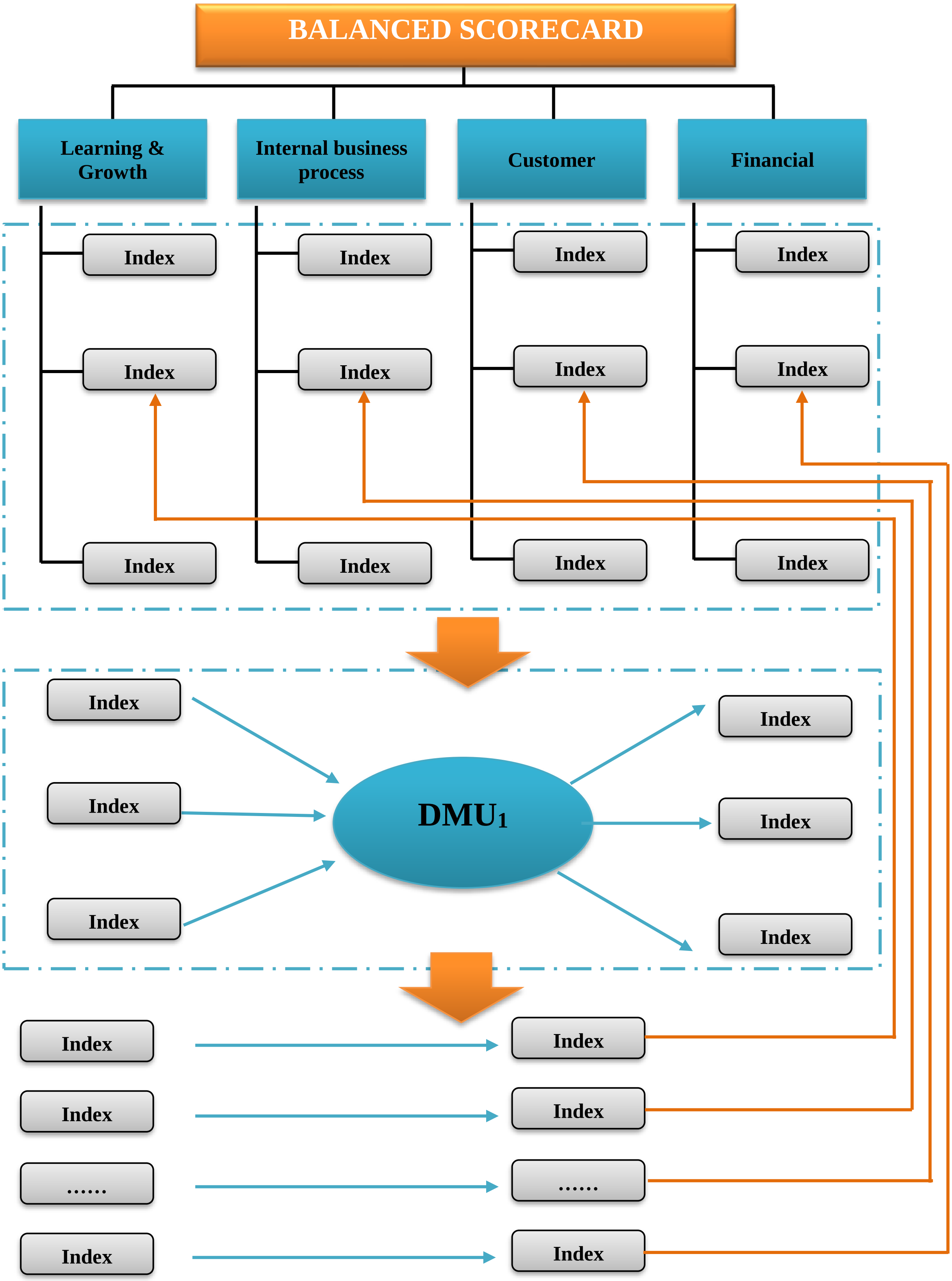
4. Both the DEA and BSC techniques provide recommendations for organizations' managers. The DEA does so by determining the inefficiency sources and providing a potential solution to help inefficient organizations to become efficient, while the BSC provides future insights through its financial perspective, which is based on past performance, and the other three nonfinancial perspectives.

The first step in applying the combined DEA-BSC model is the organization's recognition by determining the targets and strategies of each organization. Then the BSC determines the indicators required to measure each perspective. The second step is to perform the performance evaluation, where the selected indicators of the BSC will be categorized into inputs and outputs in order to implement the DEA technique. Thirdly, using the DEA, the potential improvements can be determined for each organization included in the analysis. Finally, benchmarks are set for the following performance evaluation process and providing recommendations for future improvements (Najafi, Aryanegad, Lotfi, & Ebnerasould, 2009).

Applying the combined DEA-BSC model brings numerous advantages. It provides managers with more accurate and comprehensive information. Chen and Chen (2007) stated that within the combined model, while BSC evaluates the organization's performance briefly, it provides a comprehensive view through the four perspectives. Then, the DEA completes the performance evaluation process by providing a more in-depth analysis based on inputs and outputs. The DEA is able to assess the efficiency level of each organization compared to the others, determine the inefficient organizations, detect both efficient and inefficient factors that can affect the productivity and efficiency level of the organization, provide potential improvements for the inefficient organization to convert to an efficient one, and determine appropriate benchmarks that are needed to enhance the performance of an organization (Mostafa, 2007). Lastly, the combined DEA-BSC model (Figure 2.14) provides a complete view of the organization's performance.

Furthermore, Rickards (2003) mentioned that the combined DEA-BSC model has the capability to conduct potential improvements. Once the BSC provides the DEA with the required appropriate outputs and inputs, then the DEA can provide managerial information, given the required performance measures. In other words, the combined model helps to obtain the required efficiency level, as it analyses multiple inputs and outputs concurrently, determines by what proportion the inputs should decrease to produce the determined amount of output and by what proportion the outputs should increase by using the original amounts of inputs.

Figure 2.14: The combined DEA and BSC model



Source: Alvandi and AzamMasoumi (2012)

It has been proposed that the level of efficiency provided by the combined model is based mainly on the various integrations of inputs and outputs, which means that the outcomes provided by the DEA model rely mainly on the selection of inputs and outputs (Frigo & Krumwiede, 2000). Moreover, Serrano-Cinca, Fuertes-Callén, and Mar-Molinero (2005) insisted that the DEA model should not include superfluous information. In this situation, the BSC provides a solution for these two concerns, as Kaplan and Norton (1992) proposed that the BSC limits the number of measures used to assess organizational performance and concentrates on key success factors.

In general terms, Ebnerasoul, Yavarian, and Azodi (2009) stated that the outcomes of applying the proposed DEA-BSC model are as follows: Show the ideal unit specifications (input/output) that have occurred; Rank the units based on the ideal or efficient organization; and Motivate other units/organizations to perform more efficiently

Broadly, it can be concluded that BSC and DEA complement each other. Additionally, Ebnerasoul et al. (2009) stated that applying the combined DEA–BSC model enhances the organization's ability to achieve three main common objectives: "Achieving strategic objectives (effectiveness goal); Optimizing the usage of resources in generating desired outputs (efficiency goal), and Obtaining balance" (p.45).

2.5 Summary

Due to the multiple variables (inputs and outputs) involved, assessing organizations' performance has been considered to be a complicated function. One of the most commonly applied techniques to accomplish the task of evaluating organizations' performance is the BSC. Nevertheless, DEA is a more suitable technique when comparing the efficiency levels of various organizations in quantitative terms.

While the original purpose of the DEA was to evaluate the performance of not-for-profit organizations, it is sufficiently flexible to be applied to for-profit organizations. The two main models of the DEA are the CCR model, which evaluates overall efficiency, and the BCC model, which distinguishes between technical and scale inefficiencies.

DEA is a relatively straightforward yet comprehensive method of efficiency measurement. The advantages of applying the DEA have been addressed by numerous studies. For instance, Thanassoulis (1996) argued that the DEA is a non-parametric approach which depends on transforming inputs into outputs in order to determine the optimum amount of both inputs and outputs (maximum output produced amount using a given amount of inputs or the minimum input amounts required to produce a given output amount), produces concurrent comparisons by integrating different inputs and outputs (Avkiran, 2002), and takes into consideration a combination of information instead of concentrating on particular information (Chang & Lo, 2005). Furthermore, Basso et al. (2018) stated that "while DEA is widely used in many industries, it does require open and honest engagement by managers in reporting their figures. Beyond that, a prudent and systematic application of the process should yield useful and, perhaps even more importantly, actionable information regarding an organizations efficiency" (p.83).

Accordingly, DEA has been considered as the most suitable technique which represents an appropriate starting point for specifying balanced performance. To sum up, the advantages of the integrated DEA-BSC method are as follows:

1. Determination of idealistic unit (organization): the selection of the ideal combination of inputs and outputs, obtained from the ideal (efficient) determined organization, increases the competitiveness of the organizations and motivates them to do their best to achieve a higher efficiency level and enhance their productivity.

2. The improvement of ranking system: as organizations will be ranked based on the efficient organization (ideal unit), which in return provides a fairer and more accurate ranking to the other organizations.

3. Motivating organizations' staff: an efficient organization with a 100% efficiency level will strive to achieve continuous improvement by applying creativity and innovation to its processes. This will encourage the organization's staff to concentrate more on continuous improvement and benchmarking.

4. Providing the opportunity to eliminate the shortcomings of both the BSC and the DEA.

This chapter has introduced the theoretical background to the main variables of this study and set out the importance of the combined DEA-BSC model. The next chapter will present and analyse the literature review in order to define the relationship between the variables and determine the gap(s) in the extant research.

Chapter Three: A Review of the Literature

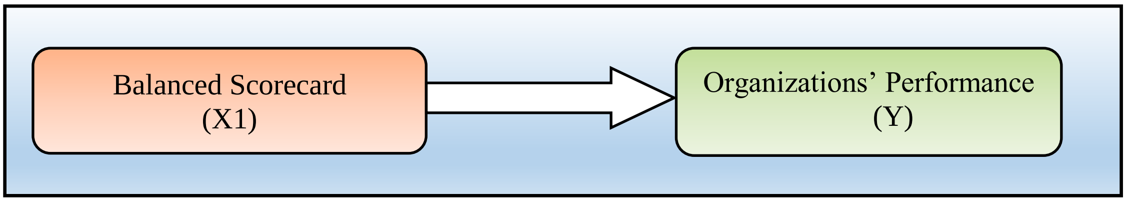
3.1 Introduction

This chapter provides an overview of previous research on BSC, DEA and their relationship with organizations' performance. It also shows the impact of integrating BSC and DEA on improving organizations' performance assessment. For this purpose, the literature review for the research is classified into three groups, which deal with the main variables of the research. The main variables are BSC, DEA, and Organization Performance. The first group of studies in the literature review addresses the relationship between BSC and organization performance. The second group addresses the relationship between DEA and organizations' performance. The third group addresses the integration between BSC and DEA and their relationships to organization performance. The chapter ends by evaluating the literature review and determining gaps in knowledge.

3.2 The relationship between BSC and organizations' performance

The first group of studies in the literature review represents the relationship between BSC and organization performance. In this group, BSC represents the independent variable or exogenous variable. The organization's performance represents the dependent variable or endogenous variable. Figure 3.1 represents the relationship between the two variables.

Figure 3.1: The relation between BSC and Organization Performance



Source: Prepared by the Researcher

BSC has grown to be one of the most widespread management control practices among public and private organizations and has therefore become the topic of many scientific studies and other literature, which demonstrates the importance and advantages of this managerial technique.

Using the case study method in a tourism organization, Kartalis, Velentzas, and Broni (2013) analysed the theoretical and empirical concepts of the BSC technique, its strengths and weaknesses and the hierarchical steps required to implement it in a specific sector or industry. The findings revealed that BSC is applicable as a performance measurement for an industry in Greece. Furthermore, the four perspectives provide a conceptual framework for translating strategic goals into performance measurements that measure the consequences of applied strategies and provide remarks on the performance of strategic initiatives.

Similarly, Zin, Sulaiman, Ramli, and Nawawi (2013) applied a case study method to investigate the role of the BSC to obtain the desired transformation, the function of management accountants and the most important factors for applying the BSC technique successfully in a chosen Malaysian governmental organization. The results showed that in order to ensure the successful implementation of BSC, the roles of management accountants need to be expanded to encompass active involvement in project management. As such, they have to obtain suitable communication and interpersonal expertise, broad business awareness and strategic thinking abilities. Communication and leadership talents, determination and perseverance are vital characteristics of organizational leadership. Moreover, the results display the importance of adherence from the top management to facilitate the application of BSC.

Based on one of the nonfinancial perspectives of BSC, namely the Internal Business Process Perspective, Weerasooriya (2013) used BSC to examine eleven of the fifteen universities in Sri Lanka. The sample size for this study includes all management faculties in Sri Lankan Universities. A thirty-item questionnaire was applied to obtain data from the heads of each department in every Management Faculty. Items were on a Likert scale and the data were tested using the Statistical Package for Social Sciences. The outcomes of this study can be applied to improve strategic plans for the management faculties in each university and promote the achievement of organizational objectives through Internal Business Process activities. Moreover, a high percentage of staff members recognized the importance of establishing an awareness program about the BSC.

Alolah, Stewart, Panuwatwanich, and Mohamed (2014) measured Saudi school safety performance using the third-generation BSC framework, considered to be an appropriate and strong framework that captures the extensive leading and lagging factors of business performance. To enhance the safety performance of Saudi schools using the BSC, firstly; the conceptual framework was created and reviewed by eighteen Saudi education experts. Then, a questionnaire was designed and completed by two hundred participants, including teachers, school executives, and ministry of education officers. Applying the partial least square, the study proves the importance of applying the BSC to enhance the school safety system. Another study involving schools was conducted in Turkey by Yüksel and Coşkun (2013); the study proposed that in order for schools to be strategy-focused and to serve their goals in a better way, they should apply BSC as a strategic performance management technique.

Since sport is considered as one of the most extensive and important sectors managed by the government in Turkey, Ekmekçi (2014) applied the BSC approach to the Ministry of Youth and Sports as a strategic management technique. This study aimed to assess the Ministry's strategic plan based on both the financial and nonfinancial perspectives of BSC. The indicators of BSC techniques were defined using the mission, vision and strategic objectives. Finally, the results were assessed. The outcomes revealed that in order to improve performance status, sports organizations should apply BSC. Furthermore, Dimitropoulos, Kosmas, and Douvis (2017) demonstrated the usefulness of the BSC in a public non-profit sports organization in Greece. The findings showed that implementing the BSC set the basis for effective performance management by improving staff skills and abilities, as well as enhancing the quality of the services introduced.

Another study applied in Turkey was conducted by Erbasi (2014). This study aimed to set up an effective performance assessment model using the BSC for small municipalities. The BSC was used as a strategic management technique and applied to data from three municipalities in Konya in the Central Anatolia Region of Turkey. The results of the study highlighted the importance of applying the BSC model in all municipalities in Turkey.

To assess the performance of innovation processes, Ivanov and Avasilcăi (2014) created a cross-sectional design using three case studies from different industries: semiconductor, distribution, and electric field organizations. The main aim of the study was to determine the key indicators within the organizations that were utilized to measure innovation processes. The study involved organizations that already applied the BSC to examine the performance of their innovation processes. The main finding was the analytical framework established by using the main indicators of the organization to assess the performance of innovation processes.

Ozturk and Coskun (2014) provided a theoretical background to the application of BSC as a strategic management tool in the banking industry. The main target of this study was to review previous studies that addressed the role of BSC practices in the banking sector. Furthermore, this study contributes to the literature by providing worldwide examples from various regions. Results showed that for banks, it will be more valuable to rely on both the financial and nonfinancial indicators of BSC instead of depending on financial performance alone in terms of evaluating performance with a holistic approach. Another study in the banking industry to examine the interrelations between the four BSC perspectives was conducted by Zahoor and

Sahaf (2018). Data were collected from several branches of two Indian retail banks. The findings proved the existence of interrelations between the four BSC perspectives, and also indicated that the customer perspective has the highest level of impact on financial performance.

Relying on surveys on luxury hotels in Turkey, Türüdüoğlu, Suner, and Yıldırım (2014) aimed to identify the main targets under the BSC perspectives and examine the strength of relationships between the perspectives. Moreover, the study took into consideration the managers' points of view about the ranking of the four BSC perspectives. The study selected twenty hotels located in Antalya and Bodrum in Turkey, as they were considered the most important tourist attraction centres that generated the highest percentage of the revenue from the hospitality industry. According to the ranking of the BSC perspectives, the analysis showed that the highest priority for all managers was given to the financial perspective, followed by the customer perspective, internal processes, and learning and growth respectively. Regarding the relationships between the four perspectives, it was found that the customer perspective was strongly affected by the learning and growth perspective. In contrast, another study set out to rank the four BSC perspectives in the banking industry (Rostami et al. (2015). The findings revealed that priority was given to the customer aspect as the first cluster, followed by the financial aspect, the internal processes aspect, and finally the learning and growth aspect.

To address a gap found in the literature, which is that there are no strict performance assessment tools in the hospitality industry, Elbanna et al. (2015) applied BSC as a technique to assess a sample of 312 hotels in the United Arab Emirates and Qatar. The results showed that even if managers did not actually apply the BSC approach, they could distinguish between the different perspectives of the BSC.

Rasoolimanesh, Jaafar, Badarulzaman, and Ramayah (2015) aimed to develop a conceptual framework to simplify the implementation of the City Development Strategy. A questionnaire survey was applied to obtain data from stakeholders in the City Development Strategy planning process. They used Partial Least Squares structural equation modelling to analyse their data. The outcomes of the structural model showed that the City Development Strategy implementation is highly affected by stakeholders, financial management, and leadership. Furthermore, the findings indicated a significant causal relationship between the indicators adopted from the BSC model.

Shukri and Ramli (2015) applied the BSC to evaluate the organizational structure and performance of 97 Malaysian private hospitals. The study used a structured questionnaire focusing on top management's perceptions to collect data. Thirty-nine responses were received. The findings revealed that a large percentage of Malaysian private hospitals that applied the BSC to assess performance were highly centralized and formalized.

Weerasooriya (2015) empirically evaluated the performance effectiveness of 303 non-governmental organizations in Sri Lanka using the financial and nonfinancial perspectives of the BSC. The main objective of the study was to demonstrate the influence of strategic planning on the effectiveness of the organization's performance. Moreover, a fifth perspective was added to the BSC, namely volunteers' development. Findings have indicated a statistically significant difference within the four perspectives of the BSC between the strategic and non-strategic planning performance effectiveness scales. The perspectives affected were customer, internal business processes, learning and growth, and volunteers' development. The findings did not show any difference regarding the financial perspective. Additionally, it was found that a large percentage of non-governmental organizations in Sri Lanka did not apply the BSC as a performance evaluation tool.

Using a Saudi hospital as a case study, Alharbi et al. (2016) applied the BSC at the electronic health department. The main aim of the study was the implementation of Cloud Computing combined with four financial and nonfinancial perspectives of the BSC, namely the learning and growth perspective, the internal process perspective, the customer perspective, and the financial perspective. The findings of this study provide guidelines for similar projects. Additionally, this study contributes to the literature by combining cloud computing with the four perspectives of the BSC.

Fedulova, Medvedev, Kosinskiy, Kononova, and Pobedash (2016) applied the BSC in the agribusiness industry. The study proposed to evaluate performance efficiency using the BSC. Its main target was to detect the optimum parameters needed for the modelling of agribusiness organizations based on the balanced scorecard. The findings illustrated that the model based on the BSC can play a vital role in solving difficult problems regarding the strategic management of agribusiness enterprises.

The main objective of de Andrade Guerra et al. (2016) study was to monitor environmental education programs in universities. To accomplish this objective, the study developed a BSC strategy map. Firstly, the primary and sub-indicators were selected by reviewing previous studies. Then, these indicators were evaluated by fifteen experts in the sustainability research area. Finally, the chosen indicators were used to build a decision tree that supports the BSC perspective. The main contribution of this study is that it represents a guideline to aid universities to implement and monitor environmental programs.

Lesáková and Dubcová (2016) examined whether the BSC is applicable and well known in organizations in the Slovak Republic. The questionnaire was distributed in electronic form and 284 responses were statistically analysed. The results revealed that only 13% of respondents knew about the BSC and applied it, while 9% knew the method but had not applied it. More than 77% did not know the BSC.

To identify the factors that would affect the development of BSC in Spanish organizations in the electric power industry, Sánchez-Ortiz, García-Valderrama, and Rodríguez-Cornejo (2016) analysed the strategies and common objectives of the five main electricity organizations. The mission and vision of the Spanish electricity sector were assessed by applying the BSC. Then, common objectives and strategies were classified for each BSC perspective. Findings showed that applying the BSC will enhance the transparency in the electricity sector.

Using a survey sample of 247 managers in the Chinese manufacturing industry at the organization level, Xi (2016) examined the appropriateness of applying the BSC for processing information in organizational context. Theoretically, positive outcomes are expected from applying the BSC. The results proposed that the outcome of applying BSC differed depending on the method of application.

Cooper et al. (2017) showed how the BSC has been developed and used as a management practice. Moreover, the study recognized different aspects of the evolution of BSC. The study contributes to the literature in two dimensions. First, it discusses how BSC as a management accounting technique is made practical through time. Secondly, it examines the procedures of the evolution and transformation of the technology by focusing on human and technology interaction.

Dinçer, Hacıoğlu, and Yüksel (2017) applied BSC to assess the performance of nine European airlines. The findings identified that the customer perspective is the most important, whereas the learning and growth perspective has the lowest importance. Furthermore, while the learning and growth perspective has no impact on the other perspectives, both the financial and the customer perspective have a significant impact on the other BSC perspectives. Another study, conducted by Tubis and Werbińska-Wojciechowska (2017), theoretically examined BSC implementation in the transportation industry at a Polish market and supported the outcomes of the previous study by Dinçer et al. (2017).

Using a Canadian case study of an Ontario community hospital, Porporato, Tsasis, and Marin Vinuesa (2017) examined the cause-and-effect relationship between the four BSC perspectives that was proposed by Kaplan and Norton in their original BSC generation. The findings of the study do not support the assumption of a cause-and-effect relationship assumption and the authors suggest that this may be the reason for the ineffective use of the BSC. Another study conducted within the healthcare sector was by Gao et al. (2018), using a case study of five Chinese hospitals and collecting data using questionnaires. The main target of the study was to create an evaluation indicator system which provides recommendations for improving hospitals' performance.

While most of the literature that addressed the impact of using the BSC to evaluate organizational performance focused on large organizations, Malagueño, Lopez-Valeiras, and Gomez-Conde (2018) examined the impact of applying the BSC in small and medium-sized enterprises. The sample consisted of 201 small and medium-sized enterprises from the food and beverage industry in Spain. To test the hypotheses, a survey was conducted between February and May 2011. The results showed that firms applying the BSC as a feed-forward control tool had a higher level of financial performance and exploitative innovation.

The increased application of the BSC within numerous contexts is evident in various areas: for instance, applying the BSC in the field of assessing supply chains, research and development, E-commerce, enterprise resource planning systems, and project management, as well as in evaluating the performance of non-profit organizations, banks, hotels, and universities. Table 3.1 summarizes the major studies addressing the relationship between the BSC and organizations' performance and shows the site of application of the study and the sector.

Table 3.1: A summary of major studies of BSC and organization performance

Sector	Author(s)	Year	Site of Application
Healthcare	(Naranjo Gil)	2010	Spain
	(El-Jardali, Saleh, Ataya, & Jamal)	2011	Lebanon
	(Chen, Hou, & Chang)	2012	Taiwan
	(Shukri & Ramli)	2015	Malaysia
	(Alharbi et al.)	2016	Saudi Arabia
	(Porporato et al.)	2017	Canada
	(Gao et al.)	2018	China
Education	(Rabbani et al.)	2010	Pakistan
	(Tseng)	2010	Taiwan
	(Yüksel & Coşkun)	2013	Turkey
	(Weerasooriya)	2013	Sri Lanka
	(Alolah et al.)	2014	Saudi Arabia
	(de Andrade Guerra et al.)	2016	Brazil
	(Alani, Khan, & Manuel)	2018	Oman
Tourism	(Huang, Chu, & Wang)	2007	China
	(Vila, Costa, & Rovira)	2010	Spain
	(Kartalis et al.)	2013	Greece
	(Kala & Bagri)	2014	India
	(Türüdüoğlu et al.)	2014	Turkey
	(Elbanna et al.)	2015	UAE and Qatar
Governmental	(Asosheh, Nalchigar, & Jamporazmey)	2010	Iran
	(Naranjo Gil)	2010	Spain
	(Steinke, Webster, & Fontaine)	2010	Canada
	(Sundin et al.)	2010	Singapore
	(Wu, Tsai, Shih, & Fu)	2013	Malaysia
	(Erbasi)	2014	Turkey
	(Dimitropoulos et al.)	2017	Greece
Transport	(Jafari, Rezaeenour, Akhavan, & Fesharaki)	2010	Iran
	(Vogt, Leonhardt, Köper, & Pennig)	2010	Germany
	(Dinçer et al.)	2017	Europe
	(Tubis & Werbińska-Wojciechowska)	2017	Poland
Industrial	(Montava, García, Bonet, & Díaz)	2010	Sweden
	(Xi)	2016	China
	(da Costa Ferreira)	2017	Portugal

Source: Prepared by the Researcher

It can be noticed that the implementation of the BSC approach in various industries has produced mixed experiences and remarks. Most of the studies recognized the importance of the BSC as a management technique that enhances organizations' performance assessment. Application of the BSC has also achieved balance by taking into consideration financial and nonfinancial indicators and short- and long-term measures (Yadav, 2011). To clarify, the experiences can be summarized as follows:

- BSC helps in assessing performance in a systematic manner;
- BSC is considered as a comprehensive technique for strategy development;
- BSC provides a template or guidelines for performance measurements which can be modified according to the organization's requirements;
- Although it is a comprehensive tool, in some cases, the four perspectives are not sufficient;
- It is difficult to identify the measures of each perspective;
- The implementation of BSC is found to be quite difficult.

Despite its popularity, many authors and practitioners have criticized the BSC and started to highlight its shortcomings and pitfalls. The weaknesses and gaps associated with the application of the BSC had been addressed by several studies. These opponent studies have considered and analysed articles that address the strengths of the BSC, the usefulness of implementing it, and the difficulties faced by organizations during the implementation process Table 3.2 shows the criticisms highlighted in the literature.

Table 3.2: Criticism Highlighted for BSC

Author(s) /Year	**Criticism Highlighted**
Atkinson et al. (1997)	• "BSC model may not be coherent with its stakeholders' approach to performance measurement" (p.100). • "BSC focuses primarily on top-down performance measurement which makes double loop learning difficult" (p.101).
Dinesh and Palmer (1998)	• The application guidelines of BSC are not fully clear. • The human relation view is not recognized.
Schneiderman (1999)	• BSC focused on high-level goals without breaking them into the sub-process level. • "Lack of quantitative linkage between non-financial and expected financial results" (p.32).
Neely and Bourne (2000)	• "70% of BSC implementations fail" because of inappropriate design and implementation failure" (p.4). • "BSC approach has no mechanism to select metrics and targets" (p.6). • "The causal relationship between perspectives' measures reflect more management's subjective understanding" (p.7).
Norreklit (2000)	• BSC does not take into consideration the effect of competition and technological developments. • The top-down control approach is questionable in BSC.

Rousseau and Rousseau (2000)	• "Balance" and "best practice" consistency or syndrome. • Missing links to human resources process.
Ahn (2001)	• Filtration for selecting goals and objectives. • Difficulties in determining measures. • Complexities in cause-and-effect chains.
Bourne, Neely, Platts, and Mills (2002)	• The human factor is ignored. • Environmental and social aspects are missing.
Meyer (2003)	• The absence of a cause-and-effect relationship between financial and nonfinancial measures. • Difficult to apply in large organizations.
Marr and Adams (2004)	• It has been proved that the learning and growth perspective is the weakest perspective of the BSC.
Akkermans and Van Oorschot (2005)	• "The concept of causality is not in all implementations of BSCs equally well developed" (p.933).
Pessanha and Prochnik (2006)	• Ignoring the interests of stakeholders and focusing on the interests of the shareholders. • The lack of employee involvement in its definition of objectives and measures.
Molleman (2007)	• Limitation of implementing BSC because of inflexibility
Bianchi and Montemaggiore (2008)	• The BSC does not take into consideration the effect of dynamics existing in the system. For example: time delays between cause and effects.
Sushil (2009)	• Causal links are not clearly defined. • The determination of specific measures is quite difficult. • No specific mechanism to classify performance measures in four perspectives.
Antonsen (2010)	• Causing work overload for some departments to collect new data required to implement the BSC.
BizShifts (2010)	• Lack enough knowledge about the BSC in bottom line, which is considered as a significant limitation during implementation. • Puts the success or failure of the BSC on senior management because of its focus on top-down design.
Kraaijenbrink (2012)	• BSC is not suitable to apply to service industries. • "Disagrees with practitioner literature suggestions that the BSC improves strategy awareness, communication, execution, and achievement" (p.113).

Madsen and Stenheim (2014b)	• The ability of each organization to implement the BSC in a way that serves their business purposes and needs because of the lack of conceptual stability.
Awadallah and Allam (2015)	• "The concept of the BSC has no clearly defined relationship with organization performance, the objective and definitions of measures exclude key stakeholders, lacks the definition of key success factors necessary for identifying KPIs, and the four categories limit the view of the organization" (p.98). • "In practice, the BSC focuses resource to achieve its goals leading to underutilization of organizations' potential beyond the targets of the BSC; and one-way linear cause-and-effect relationships and promotes closed innovation" (p.98).
Fooladvand, Yarmohammadian, and Shahtalebi (2015)	• "Significant tensions and conflict existed among top managers and partly because of inaccurate, subjective and lingual nature of BSC indexes and using inappropriate models for evaluation" (p.952). • "Balanced Scorecard in definition is a set of quantitative indexes consolidating the performance values at the individual level (i.e., performance indicators) and also for integration of weak indexes" (p.952). • "Integrating the result is done subjectively by the users of BSC" (p.952).
Askarany and Yazdifar (2018)	• "Ignoring the risks, environmental and sustainability factors as well as neglecting the concerns/rights of other relevant stakeholders (besides customers) are the key shortcomings of the BSC, which could undermine its diffusion in practice" (p.78).

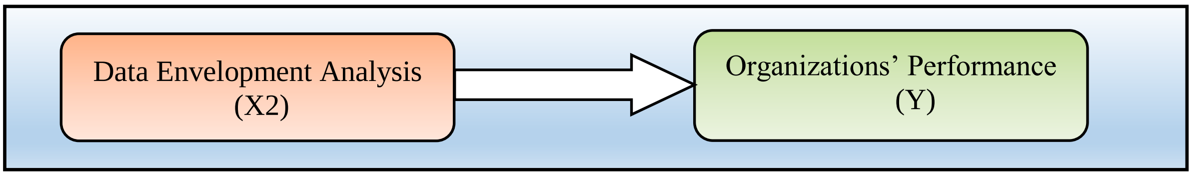
Source: prepared by the researcher

Therefore, as seen in Table 3.2, there are numerous criticisms of the BSC technique. While some of these criticisms have been addressed and resolved in the literature, others remain unsolved, and have therefore gained the interest of future studies. Gradually, these criticisms have prompted researchers to think beyond BSC and they have started trying to solve its pitfalls by developing new forms of BSC by adding new perspectives. Some researchers have integrated BSC with other techniques to help in the process of performance evaluation. Therefore, recent research suggests integrating another model, namely the DEA, to be able to overcome some of the drawbacks of the BSC approach.

3.3 The relationship between DEA and organizations' performance

The second group of studies examined in this literature review represents the relationship between DEA and organizations' performance. In this group, DEA represents the independent variable or exogenous variable, while organizations' performance represents the dependent or endogenous variable. Figure 3.2 represents the relation between the variables.

Figure 3.2: The relationship between DEA and organizations' performance



Source: Prepared by the Researcher

Most previous studies of DEA have focused on the methodologies and procedures for applying it. For example, Seiford and Thrall (1990) addressed the development of the original DEA model, while Seiford (1996) followed the evolution of DEA since 1978. Cooper et al. (2007) examined DEA models and required indicators. Cook and Seiford (2009) surveyed the development of DEA since 1978 for a period of 30 years.

All these studies gave details on methodological subjects such as DEA models, guidelines for choosing variables, data variation, etc. However, Liu, Lu, Lu, and Lin (2013b) stated that "there is no survey in regards to the development of DEA applications. In total, 67% of the (DEA) articles presented a real-world application and banking, education, healthcare, and hospital efficiency were found to be the most popular application areas" (p.893). In order to fill this gap, Liu et al. (2013b) introduced a literature survey, provided graphs for the main DEA development paths, and mentioned that the major DEA applications are banking, education, healthcare, and hospitals. In the following section, the study will discuss these various applications.

3.3.1 Banking

Examining fourteen savings bank branches, Sherman and Gold (1985) conducted a seminal study that utilized DEA to assess efficiency in the banking industry. They applied the classical CCR model. The results proposed that applying the DEA model provide meaningful insights that are not obtainable from other methods. Another precocious study was that of Parkan (1987), who investigated the efficiency of Canadian bank branches.

A significant study that followed Sherman and Gold's work is that of Rangan, Grabowski, Aly, and Pasurka (1988), which primarily applied the two-stage DEA model to the banking industry. This was followed by two studies by Berg, Førsund, and Jansen (1992), and Berg, Førsund, Hjalmarsson, and Suominen (1993), which examined the growth of banks' productivity in Norway and Nordic countries by applying the Malmquist index.

Subsequently, with a sample of 174 Italian banks, Favero and Papi (1995) applied the two-stage DEA method. Both the survey by Berger and Humphrey (1997) and the introductory study by Thanassoulis (1999) motivated researchers to apply the DEA in the banking sector by providing more detailed issues that can be determined in the future through DEA. Furthermore, the application of the two-stage DEA model to the banking industry is the main similarity of the three studies of Seiford and Zhu (1999), Luo (2003), and Lo and Lu (2006).

Based on a sample of ten Syrian private banks for a period of four years starting from 2006, Khaddaj (2010) applied the DEA to assess the efficiency level of banks. The study examined the efficiency of each bank based on the operating and intermediation levels. The Intermediation Approach assesses the efficient use of bank resources to achieve new investments. The findings detected that on their operating level, most Syrian banks are inefficient. However, at their intermediation level, they tend to be more efficient. Accordingly, the study provides a recommendation that the Syrian banks could further utilize their resources to achieve revenues and/or reduce their expenses.

In order to benchmark Peruvian banks based on their efficiency, Charles et al. (2011) applied the DEA to examine the efficiency for the period from 2000 to 2009. Their results showed an increasing trend in technical efficiency. Additionally, multinational banks performed better than domestic banks throughout the period, excluding the year 2007, when the efficiency performance for both the groups sharply declined.

Eken and Kale (2011) applied DEA to examine the efficiency levels of 128 Turkish bank branches. The results showed that there is a negative relationship between the branch size and efficiency level, which means that as size increases, efficiency decreases. Furthermore, Singh, Kedia, and Sisodiya (2012) used the DEA to rank eighteen different private and public sector banks in India based on their efficiency. The DEA model has been used as a non-parametric technique to investigate the efficiency score.

Other studies have focused on review the literature addressing the application of the DEA in the banking industry. For example, Liu, Lu, Lu, and Lin (2013a) stated that "all papers on the main paths study the performance of banks in countries all over the world. Nevertheless, the DEA models they use, and the foci of their studies, vary" (p.13). The study reviewed the sequence methods applied by the DEA, from the original CCR model to the two-stage DEA model, then to the Malmquist index, etc. Paradi and Zhu (2013) conducted a review of eighty previously published studies which applied the DEA in the banking industry in twenty-four countries. The results revealed that between 1985 and 2011, there were 275 DEA applications in the banking sector. While 195 studies examined banking institutions, eighty focused on the branch level.

Yılmaz (2013) applied DEA to assess the efficiency scores of thirty commercial banks in Turkey for a period of four years starting from 2007. Additionally, the study showed the consequences of the 2008 financial crisis on the efficiency scores of both domestic and foreign banks operated in Turkey. The findings showed that over the period from 2007-2010, the foreign banks were less efficient than the domestic banks.

Jayaraman and Srinivasan (2014) used the DEA models to develop a comprehensive efficiency index for 34 Indian banks. The study applied three models of the DEA that are different in their objectives, namely the cost, revenue, and profit models. The outcomes revealed the following: five banks are cost-efficient; nine banks are revenue-efficient, and ten banks are profit-efficient. Furthermore, only five banks are efficient under all models. It is noticeable that banks which are efficient in one model are not necessarily efficient under other models.

Another two studies applied in Indian banks using DEA were the works of Roy and Das (2015) and Bhatia and Mahendru (2015). Roy and Das (2015) used a sample of eight Cooperative Banks from 2001 to 2010 and utilized two models to assess their cost efficiency and revenue efficiency. The findings revealed considerable inefficiency in both cost and revenue models. Bhatia and Mahendru (2015) examined the technical efficiency of public sector banks in India during the period from 1990 to 2012. The findings indicated that Public Sector Banks should improve their operational efficiency, as it has a direct effect on technical efficiency.

Charles and Kumar (2014) applied DEA to evaluate the service quality of thirteen Malaysian banks. Using data from a survey of 688 customers in cooperation with previously determined service quality dimensions, they proposed a DEA model under a stochastic environment which is free from any theoretical assumptions. Unlike the conventional DEA model, which provides results with certainty, their findings revealed the positioning of the individual banks by assessing the ability of the bank to serve its customers. Furthermore, they provided an insight for management on how an inefficient bank needs to minimize the overall gap in its service.

Another study involving Malaysian banks was conducted by Ab Rahim (2015). The main target of this study was to assess the technical efficiency of Malaysian commercial banks within a period of 11 years since 2000. The findings showed that domestic banks are more efficient than foreign banks. In contrast, based on the super-efficiency results, the individual foreign banks are more efficient than individual domestic banks.

Othman et al. (2016) provided a review of the literature addressing the application of DEA to evaluate the relative efficiency of the banking sector. The study concludes that although most banks focused more on maximizing output given a certain level of input, these banks have to give more consideration to improving their managerial, technology or socio-economic efficiency.

Using a sample of 30 Brazilian banks for a period of four years since 2010, Périco et al. (2016) used the DEA to analyse their efficiency. The results provide a recommendation to the large Brazilian banks that to enhance their efficiency level, they must reduce expenses and increase revenues. Similarly, the findings of Yannick et al. (2016) support the application of DEA to evaluate banks' efficiency levels. The study used a sample of fourteen banks operating in Côte d'Ivoire from 2008 to 2010.

Mirza (2017) collected data from the bank scope database for only fourteen of forty Lebanese banks from 2009 to 2013 in order to evaluate their efficiency. The study applied the Malmquist DEA method. The results showed that all the selected Lebanese banks are inefficient.

Using financial data from Taiwanese commercial banks in 2013 to explore bank efficiency after the adoption of IFRS, Chao, Yu, Hsiung, and Chen (2018) used DEA to examine profitability efficiency and marketability efficiency. The study used nineteen commercial banks listed on the Taiwan Stock Exchange Organization as the sample, of which ten were in financial holding organizations and the other nine were not. The findings showed that banks that are in financial holding organizations can achieve greater cost reductions than those that are not; however, they produce less market value. Furthermore, the main reason for inefficiency in both profitability and marketability processes for banks that are not in financial holding organizations is technology gap inefficiency.

Fernandes, Stasinakis, and Bardarova (2018) applied the DEA to assess the efficiency of 64 domestic commercial banks over a period of eight years, starting in 2007. The data covered five Euro areas: Greece, Ireland, Italy, Portugal, and Spain. The study applied output-oriented DEA with two inputs (interest expenses and operating expenses) and one output (total income) to measure the banks' productivity change. Data were obtained from the Bankscope database (2015 version), the World Bank, and World Development Indicators. The findings showed that there is a negative relationship between liquidity, credit risk, and banks' productivity, whereas there is a positive relationship between capital, profit risk, and banks' productivity.

The "financials" industry is excluded from the current study. This includes banks, insurance, real estate, and financial services, due to their different nature from other sectors. This is because, in order to apply the DEA appropriately, all included DMUs and data utilized should be homogeneous (Serrano-Cinca et al., 2005). The previous section has nonetheless demonstrated that DEA is an important technique in evaluating banks' performance and that it is applicable within a range of countries. Hence, it can be a point for future research.

3.3.2 Health Care

Regarding the implementation of the DEA technique in the health care area, the two main studies are those of Nunamaker (1983) and Sherman (1984). The first published paper in this regard was by Nunamaker (1983), who focused on nursing service efficiency. Sherman (1984) then applied DEA to a group of hospitals and showed that it plays a considerable role in evaluating hospitals' inefficiency. Subsequently, Banker, Conrad, and Strauss (1986) applied the DEA model to a sample of North Carolina hospitals.

Respectively, Linna (1998) and Giuffrida and Gravelle (2001) examined the efficiency of hospitals and primary care services by applying the DEA. Worthington (2004) and Hollingsworth (2008) both conducted surveys of literature related to the application of DEA in the healthcare sector and showed the progression of its implementation. In brief, Hollingsworth (2008) stated that most previous studies in the healthcare area that aim to evaluate efficiency scores tend to rely on DEA.

DEA has been applied to address the increasing importance of evaluating quality in the nursing home industry. It has been used to develop strategies for cost control and performance improvement. Applying DEA to 38 nursing homes, Shimshak, Lenard, and Klimberg (2009) utilized three techniques to eliminate the problems that originate when quality output measures are added to the DEA model, namely the Two-Model Approach, Separate Quality Efficiency, and Operating Efficiency. Then a case study was used to investigate the findings of applying these three techniques to a DEA model. The finding showed that the Separate Quality Efficiency and Operating Efficiency techniques are the most effective in ensuring that DEA results distinguish between high and low-quality performance.

Alamin and Yassin (2013) applied DEA to evaluate the efficiency of services introduced by Khartoum governmental hospitals. A sample of fifteen hospitals was used for the year 2012. The findings showed that the level of technical efficiency of governmental hospitals at Khartoum was seventy percent, which means that there are factors causing a gap and affecting the performance efficiency level. The study suggested that these factors can be environmental and internal management factors

Another study that aimed to evaluate the relative technical efficiency of public health units in Greece over a five-year period was carried out by Farantos and Koutsoukis (2016). The study takes into consideration the consequences of the financial crisis in order to mitigate inefficient practices in the healthcare sector. A set of 105 health units was selected to apply the DEA. The findings revealed no upward trend in efficiency scores. On the contrary, the findings showed a downward trend in efficiency scores. Similarly, the Vitezic, Segota, and Cankar (2016) main objective was to assess the public health units' efficiency level. Data for two years (2014 and 2015) were collected for a group of twelve health units. The results recognized the importance of DEA in providing managers with a valid technique to evaluate the efficiency level of each unit.

Arfa, Leleu, Goaied, and van Mosseveld (2017) applied DEA to measure the capacity utilization of public district hospitals in Tunisia for 2000 and 2010. Findings revealed that the unused capacity was estimated at 18% in 2010 vs. 13% in 2000. Furthermore, it was noted that Public District Hospitals were under-utilizing their production capacity for both 2000 and 2010. It is estimated that the unused capacity reached 5% in 2000 and 8% in 2010.

3.3.3 Tourism

Based on the UK Standard Industrial Classification of Economic Activities, there are five tourism industries: transportation, accommodation, food and beverage services, recreation and entertainment, and travel services. The two industries that have attracted most research attention in applying the DEA are transportation and accommodation. In the transportation industry, there are two main independent areas of research. Some studies have evaluated the efficiency level of ground transportation systems such as railway and bus services, while others have focused on air transportation. In the latter category, the leading article was by Schefczyk (1993). This study evaluated the efficiency of operational performance in a sample of fifteen international airlines. Schefczyk (1993) established the foundation for future studies in the airline industry. Other studies that applied the DEA to assess airports' performance efficiency levels are summarized in Table 3.3.

Table 3.3: Prior literature assessing airports' efficiency using DEA

Author	***Sample Data***
Gillen and Lall (1997)	21 airports in the US, 1989- 1993
Murillo-Melchor (1999)	33 airports in Spain, 1992-1994
Sarkis (2000); Sarkis and Talluri (2004)	44 airports in the US, 1990- 1994
Fernandes and Pacheco (2002)	35 airports in Brazil, 1998
Bazargan and Vasigh (2003)	45 airports in the US, 1996- 2000
Pels, Nijkamp, and Rietveld (2003)	33 airports in Europe, 1995-1997
Yoshida and Fujimoto (2004)	67 airports in Japan, 2000
Martín and Román (2006)	34 airports in Spain, 1997
Barros and Dieke (2008)	31 airports in Itally, 2001-2003
Koçak (2011)	40 airports in Turkey, 2008
Chow and Fung (2012)	30 airports in China, 2000- 2006
Ahn and Min (2014)	23 airports in Europe, 2006- 2011
Omrani and Soltanzadeh (2016)	8 airlines in Iran, 2010-2012
Yu, Chen, and Chiang (2017)	30 international airlines, 2010
Kottas and Madas (2018)	30 international airlines, 2012-2016

Source: Prepared by the Researcher

With regard to ground transportation, the seminal study was conducted by Oum and Yu (1994). The study assessed the efficiency of the railway system in 19 OECD countries. Additionally, Cowie and Riddington (1996) examined the efficiency levels of bus systems.

Applying a multiple layer DEA model to a group of nineteen European countries, Shen et al. (2011) examined road safety performance. The study used thirteen safety performance indicators in terms of road user behaviour (e.g., inappropriate or excessive speed). The findings recognized the usefulness and effectiveness of applying DEA to assess the performance efficiency level of road safety.

Fancello, Uccheddu, and Fadda (2014) distinguished between the performances of different urban networks using DEA. The main purpose of their study was to provide policymakers with technical support in the process of choosing procedures to enhance the efficiency level of urban road systems. The findings stated that "the degree of efficiency achieved by each network is meaningful only in the context in which it has been measured, and then only in relation to the specific model and sample units considered" (p.788).

Another study, conducted by Zhou, Chung, and Zhang (2014), applied DEA in the transport sector. The main target of the study was to examine the energy efficiency of China's transport sector for a period of seven years starting from 2003. The empirical results showed that the lowest efficiency rates were recorded in 2007 and 2008. Moreover, the results indicated that the financial crisis significantly affected efficiency levels.

In the context of the accommodation industry, numerous studies have evaluated the efficiency level of hotels. Two main studies that applied DEA to evaluate the efficiency of hotels in the United States were the study conducted by Morey and Dittman (1995) and Anderson, Fish, Xia, and Michello (1999). Morey and Dittman (1995) used a sample of 54 US hotels and considered ten inputs and four outputs, namely total room revenue, facilities satisfaction index, and services satisfaction index. The results showed that thirty-four hotels are inefficient. Subsequently, Anderson et al. (1999) used a sample of forty-eight US hotels and found that public ownership negatively affects efficiency scores. Furthermore, the study urged hotel managers to pay more attention to improving the growth of total productivity rate.

Another leading study that applied DEA to evaluate hotel performance was conducted by of Johns, Howcroft, and Drake (1997) in the United Kingdom. The study used a sample of fifteen hotels, with four inputs (number of room nights available, total labour hours, total food and beverage costs, and total utility cost), and three outputs (number of room nights sold, total covers served, and total beverage revenue). The study addressed the advantages and disadvantages of DEA and the empirical outcomes from DEA determined the most efficient hotels in the sample and assigned them the values of 100% while less efficient units were scored proportionately lower.

Hsieh and Lin (2010) examined the efficiency and effectiveness of 57 international tourist hotels in Taiwan by applying network data envelopment. The study provided a comprehensive performance measure of efficiency and effectiveness by assessing the managerial issues, the performance of different departments, and the performance of the hotel as a whole. This empirical study provides recommendations to managers for enhancing the overall performance of the hotel industry in Taiwan.

Subsequently, numerous studies applied the DEA approach to evaluate the efficiency, performance, and productivity of hotels. Table 3.4 summarizes the sample selection of the major studies that used DEA in the hotel industry from 1995 to 2016. The table shows that most of the examined hotels in Taiwan, followed by the United States and Portugal. Additionally, it can be noticed that most of the studies were published after 2000, which reflects that the DEA has recently started to be regarded as a significant and powerful research tool in evaluating the performance of the hotels.

Table 3.4: Prior literature evaluating hotels efficiency using DEA

Author(s) / Year of publication	***Sample Data***
Morey and Dittman (1995)	54 US hotels
Johns et al. (1997)	15 UK hotels
Anderson et al. (1999)	48 US hotels
Wober (2000)	61 Australia hotels
Tsaur (2001)	35 Taiwan hotels
Brown and Ragsdale (2002)	46 US hotels
Hwang and Chang (2003)	45 Taiwan hotels
Sigala (2003)	93 UK hotels
Hu and Cai (2004)	242 California hotels
Barros (2005)	48 Portugal hotels
Barros and Santos (2006)	15 Portugal hotels
Shang, Hung, Lo, and Wang (2008)	57 Taiwan hotels
Barros, Peypoch, and Solonandrasana (2009)	15 Portugal hotels
Neves and Lourenço (2009)	83 Portugal hotels
Hsieh and Lin (2010)	57 Taiwan hotels
Suzuki, Nijkamp, and Rietveld (2011)	103 Italy hotels
Manasakis, Apostolakis, and Datseris (2013)	50 Crete hotels
Ting and Huang (2012)	58 Taiwan hotels
Hui and Wan (2013)	25 Hong Kong hotels
Huang, Ho, and Chiu (2014)	58 Taiwan hotels
Luo, Yang, and Law (2014)	28 China hotels
Astane, Rahnama, and Zareei (2015)	31 Iran hotels
Ben Aissa, Ben Aissa, Goaied, and Goaied (2016)	27 Tunisia hotels
Poldrugovac, Tekavcic, and Jankovic (2016)	105 Croatia hotels
Ramanathan, Ramanathan, and Zhang (2016)	102 UK hotels

Source: Prepared by the Researcher

Another important industry in the tourism sector is the food and beverage industry. Gardijan and Lukač (2018) applied the DEA technique in order to assess the relative efficiency of food and beverage manufacturers from ninteen European countries during the period from 2011 to 2015. The European countries included were Austria, Belgium, Bulgaria, Croatia, the Czech Republic, Estonia, Finland, France, Germany, Hungary, Italy, Luxembourg, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden. The data were collected from the Amadeus database. Liquidity, leverage, activity and profitability ratios were calculated and used as inputs and outputs for the BCC output-oriented DEA model. The results of the analysis determined which countries have the greatest number of efficient organizations and identified the main reasons for inefficiency for organizations within each country.

3.3.4 Education

The most significant sector that attracted most researchers in the period after the development of the DEA was the education sector. There are four main DEA educational studies: Bessent and Bessent (1980), Charnes, Cooper, and Rhodes (1981), Bessent, Bessent, Kennington, and Reagan (1982), and Bessent, Bessent, Charnes, Cooper, and Thorogood (1983). Liu et al. (2013a) mentioned that "Charnes et al. (1981), Bessent et al. (1982) and Bessent et al. (1983) are particularly influential, not only to educational applications but to DEA development in general, as they are all on the main path of grand DEA development" (p.6).

There were two main streams in the previous studies. Firstly, studies examined the efficiency level of basic education. This stream includes Ray (1991), Mancebon and Molinero (2000), and Bradley, Johnes, and Millington (2001). Secondly, studies focused on evaluating the efficiency of higher education. This stream includes Bessent et al. (1983), SinuanyStern, Mehrez, and Barboy (1994), Arcelus and Coleman (1997), Johnes (2006), Worthington and Lee (2008), and Johnes (2008), who measured the research performance of Chinese regular universities.

Recently, the higher education sector is considered the main trend of efficiency studies in the education sector, as most of the studies have focused on the evaluation of universities' performance. The earliest researchers relied methodologically on the two-step contextual DEA method: for example, Ray (1991), Mancebon and Molinero (2000), and Bradley et al. (2001).

Rosenmayer (2014) reviewed several research papers to examine the appropriateness and capability of applying DEA in evaluating the effectiveness of the economy of universities. Five articles published in Canada, Australia, Great Britain, Germany, and Spain between 1998 and 2008 were evaluated. These five articles are similar in that they all applied DEA to evaluate the efficiency of universities. The outcomes of their assessments showed that all the reviewed studies focused on the method of evaluation rather than the objective of measurement. Furthermore, the articles did not compare the objectives of the selected universities.

3.3.5 Energy

Two main studies applied DEA to evaluate life-cycle energy efficiency: the first was conducted by Lins, Oliveira, Da Silva, Rosa, and Pereira (2012) and focused on eleven alternative energy sources in the Brazilian power sector, and the second was carried out by Ren et al. (2014), involving six biofuel systems in China. The findings of both studies support the main idea, which is that DEA is practically demonstrated to help in assessing energy efficiency scores.

Zhou et al. (2014) applied the DEA approach from 2003 to 2009. The study aimed to assess the energy efficiency performance of China's transport sector, and to maximize the energy-saving potential of the transport industry in thirty Chinese administrative regions. The empirical results showed that the lowest efficiency rates were recorded in 2007 and 2008. Moreover, the results indicated that the financial crisis significantly affected efficiency levels.

In Iran, Qolipour et al. (2016) applied DEA to rank the efficiency level of six wind turbines located within the Ardabil province in Iran. In the United States, Sağlam (2017) used the DEA to rank seven renewable energy technologies that generate electricity based on their efficiency scores. Similarly, Hosseinzadeh-Bandbafha, Nabavi-Pelesaraei, Khanali, Ghahderijani, and Chau (2018) applied the DEA approach to examine the efficiency of 120 peanut farms in the Guilan province in Iran. The findings of the study were based on constant and variable returns to scale and showed that in terms of pure technical efficiency, ninety farmers are efficient, whereas in terms of technical efficiency with both constant and variable returns to scale, twenty-two farmers are efficient.

3.3.6 Other Applications

To evaluate profitability, Liu (2008) applied the DEA using a sample of thirteen parks managed by ten superior theme parks within the UK. The main purpose of the study was to design a profitability index instead of using traditional financial ratios to measure profitability. The results shed light on the usefulness of applying the DEA rather than the traditional financial ratios. Moreover, the results showed that the DEA provides new insights for managers about financial measures that are not available using the ratio technique.

Lee and Saen (2012) conducted a study which aimed to improve the realization of the measurement of corporate sustainability management applying the DEA technique. A case study of a Korean electronics industry was used. The main outcome of this study is that that it offers a new insight to evaluate corporate sustainability management. This model is considered as a contribution to the literature in corporate sustainability management and its performance measurement.

With a view to enhance the evaluation of dealer performance, Gonzalez-Padron, Akdeniz, and Calantone (2014) used a sample of forty-seven office furniture dealers to design a systematic approach that will help manufacturers. The findings provide manufacturers with a holistic view of allocating sales staff. This comprehensive view plays an essential role in improving dealer efficiency, as well as introducing a complementary technique to conventional financial ratio benchmarking in detecting efficiency scores for other dealers.

Mirhedayatian, Azadi, and Saen (2014) recognized the important role of supply chain management to improve environmental performance. Therefore, DEA and a case study of ten green Iranian organizations producing soft drinks were used for evaluating green supply chain management. Furthermore, within the same area of interest in evaluating environmental performance, Wu, An, Yao, and Wang (2014) suggested that "The industry is permitted a fixed total amount of pollution in order to avoid excessive pollution" (p.96). Their study applied DEA to examine the environmental efficiencies of China's industry for a period of five years from 2007. The findings showed that some developed provinces have better performance than less developed provinces. Similarly, Tavana, Kaviani, Di Caprio, and Rahpeyma (2016) applied DEA to evaluate supply chain efficiency.

Kapelko (2016) applied DEA to examine both technical and scale inefficiency in construction organizations. They used a sample of 5706 organizations in Spain and 965 in Portugal that were operating between 2002 and 2010. The findings empirically proved that fixed assets are the most technical inefficient input for both Spanish and Portuguese construction organizations. Sveum (2016) provides evidence that two-stage DEA is a useful tool for determining productivity differences between two groups based on a group-specific characteristic.

Data from 37 organizations operating in the manufacturing sector of Pakistan were collected by Ahmad, Ishtiaq, Hamid, Khurram, and Nawaz (2017). The main objective of their study was to improve the efficiency of working capital management policies. DEA results referenced only 16 organizations as efficient, while the remainder required either an increase or a decrease in their inputs to achieve the required efficiency score.

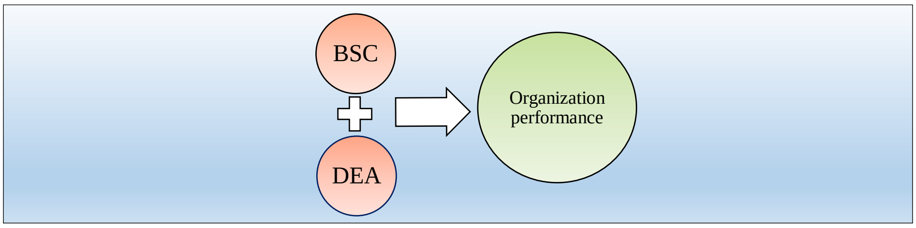
Karadayi and Ekinci (2018) applied categorical DEA to evaluate the R&D performance of European Union countries. The analysis applied the output-oriented constant returns to scale and variable returns to scale DEA models for the period from 2011-2013. The study includes twenty-eight countries, namely Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and the United Kingdom. The findings showed that "countries which have political stability and high-quality regulatory environment result in high R&D efficiency. This means that countries that are willing to demonstrate high R&D performance should create a stable environment in terms of political and regulatory issues" (p.236).

The classification in the previous section was based on the major DEA application areas or sectors. However, the empirical analysis of the current study will depend on the main industries rather than sectors using the Industry Classification Benchmark (ICB). Industry Classification Benchmark (ICB), had been defined on the Wikipedia website as "an industry classification taxonomy launched by Dow Jones and FTSE in 2005 and now owned solely by FTSE International. It is used to segregate markets into sectors within the macroeconomy. The ICB uses a system of 10 industries, partitioned into 19 supersectors, which are further divided into 41 sectors, which then contain 114 subsectors". For instance, the banking is considered as a sector in the financial industry, tourism is considered as a sector in the consumer service industry, and energy is considered as a sector in the oil & gas industry.

3.4 The relationship between the combined DEA-BSC model and organizations' performance

The third group within the literature review represents the integration between BSC and DEA and the impact of this integration on improving organizations' performance assessment. In this group, BSC and DEA represent the independent variables or exogenous variables. Organizations' performance represents the dependent variable or endogenous variable. Figure 3.3 represents the relations between these variables.

Figure 3.3: The relationships between DEA, BSC and Organization Performance



Source: Prepared by the Researcher

Although the DEA and BSC approaches are commonly applied in various industries, very few studies have examined the impact of their integration in improving the process of assessing organizational performance and providing guidelines for enhancing efficiency scores. To fill this gap, main objective of the current study is to examine the impact of this integration.

Furthermore, consistent with what has been proposed by several authors (Dyson & Shale, 2010; Ebnerasoul et al., 2009; Eilat et al., 2008; Kádárová et al., 2013; Tan et al., 2017) , the other purpose of the current study is to examine the usefulness of applying the DEA as an Operational Research technique in real operational environments and to provide considerable recommendations associated with its successful implementation in practice.

The advantages of combining several techniques to enhance performance evaluation frameworks and increase their ability to determine real-world difficulties have been discussed by Mingers and Brocklesby (1997) and Franco and Lord (2011). Furthermore, the advantages of integrating several approaches have been indicated in previous studies (Santos, Belton, & Howick, 2002; Xu & Yeh, 2012) and several authors have focused their attention on the DEA and BSC approaches (Amado, Santos, & Marques, 2012).

For instance, as discussed in the previous sections, many studies have applied DEA and BSC separately in order to evaluate the advantages of these approaches (Ahmad et al., 2017; Dinçer et al., 2017; Wang & Wu, 2006), whilst others have combined DEA analysis with other performance assessment techniques in order to better realize the DEA outcomes (Rouse, Putterill, & Ryan, 2002; Tsang, Jardine, & Kolodny, 1999). Although several fundamental developments have taken place in this area, very few studies have authenticated the combination of DEA with BSC.

The leading and first study that underlined the possibility of complementing DEA analysis with BSC in order to assess the efficiency of performance was conducted by Rouse et al. (2002). Its main objective was to develop a performance monitoring system for the productivity of the engineering service division of an international airline based on DEA and the four perspectives of the BSC. A case study was applied over a period of four years from 1993 to 1997. The study developed a performance pyramid to ease the determination of the reasons for inefficiencies with the assistance of the DEA technique. The major outcome of this study was that "while methods such as DEA provide the 'bones' of performance analysis, the measurement structure provides the 'body' for successful performance evaluation and measurement" (p.245).

Respectively, Rickards (2003) was the first study that focused on developing a DEA model taking into consideration the four perspectives of BSC. A sample of sixty-nine organizations operating throughout Europe was used. The selected outputs were: cash flow, customer commitment, internal service quality, and employee motivation. The inputs were: machine capacity, number of employees, salesroom floor space, and advertising expenditure. The main outcome of this study was to emphasize the advantages of integrating DEA with the four perspectives of BSC. Applying DEA transformed the performance measures into a global performance score. Rickards' idea of originating a distinctive DEA model comprising the different perspectives of the BSC attracted the attention of researchers in later studies.

Using a sample of fifty carriers operating in the US telecommunications industry, Banker et al. (2004) examined the association between a financial performance measure (return on assets: ROA) and three nonfinancial performance measures (number of access lines per employee, percentage of digital access lines and percentage of business access lines). The study covered a period of five years, from 1993 to 1997. The findings showed that the return on assets should be a trade-off in order to be able to increase the percentage of business access lines.

Other relevant studies developed a holistic model by incorporating BSC perspectives into the DEA methodology. For instance, Chen and Chen (2007) used this idea to examine the technical efficiency of thirty Taiwanese semiconductor manufacturers; Min, Min, and Joo (2008) used the combined model to compare the efficiency of six Korean luxury hotels for three years from 2001. In the banking context, Chen et al. (2008) collected data about the Cooperative Bank for five years from 2001 to evaluate the efficiency of bank branches. Macedo, Barbosa, and Cavalcante (2009) applied the combined DEA and BSC model to examine bank branches efficiency scores. To assess the performance of auto organizations and commercial banks in the US, Chiang and Lin (2009) applied a DEA model using four inputs and four outputs.

The publication of two studies, conducted by Eilat, Golany, and Shtub (2006); Eilat et al. (2008) achieved significant advances in this research area by revealing how the combination of the DEA and the BSC techniques can enhance their individual capabilities. Eilat et al. (2006, 2008) extended the literature through the inclusion of "weight restrictions" for each perspective of the BSC to guarantee a truly balanced assessment. Whereas Eilat et al. (2006) compared R&D projects individually, Eilat et al. (2008) applied a DEA to compare R&D portfolios of projects.

Another study in the context of R&D activities was implemented by García-Valderrama, Mulero-Mendigorri, and Revuelta-Bordoy (2009). Whereas the studies discussed previously applied a single model to integrate the DEA and BSC techniques, García-Valderrama et al. (2009) used five DEA models to examine the causal relationships between the four perspectives of the BSC. The data was selected based on a survey of ninety Spanish chemical and pharmaceutical organizations. The findings showed that for all organizations studied, the four perspectives of the BSC are highly correlated, which supports the causal relationships of the BSC.

Using real-world data from the Ministry of Science, Research, and Technology in Iran, Asosheh et al. (2010) applied a combined BSC and DEA model to evaluate information technology projects. The study proposed a new model for ranking information technology projects. The proposed approach considered five perspectives of the BSC by adding the uncertainty perspective to the four original perspectives to emphasize its role in information technology projects. The outcomes emphasized the applicability of the combined DEA and BSC model. Another study applied in Iran was carried out by Roodposhti et al. (2010). Its purpose was to evaluate six commercial banks in Iran by applying the integrated BSC and DEA model. The findings support the integrated model by obtaining acceptable results.

In order to explore the operating efficiency of the military finance centre in Taiwan, Lu and Chen (2011) developed a benchmarking managerial framework. The proposed framework incorporates three models: BSC, DEA, and cluster analysis. Operating data for twenty-eight military finance centres for the year 2006 was collected. The main contribution of the study is that it presented a benchmarking analysis that can help to improve inefficient units. Moreover, it highlights the potential strengths of the techniques applied in evaluating military financial units.

In the UK, Ramanathan and Ramanathan (2011) named the integrated BSC and DEA model as "The balanced efficiency assessment method". The integrated model was used to assess the performance of health authorities in the UK. Data were collected for ninety-four health authorities. To measure balanced performance, the study takes considered six perspectives of the BSC. Each perspective was measured using indicators listed in a comprehensive index prepared by the NHS to evaluate the performance of health authorities. These six perspectives are: health outcomes of NHS care, health improvement, fair access, effective delivery of appropriate health care, patient/care experience, and efficiency. The study used a total of thirty-two inputs and twenty-five outputs. Furthermore, the DEA model was applied separately for each of the six BSC perspectives. The findings showed that in terms of these six perspectives, there is no efficient health authority. Even if there is an efficient health authority from one perspective, it seems to be inefficient in another perspective.

Alvandi and AzamMasoumi (2012) examined the performance of automotive and spare parts organizations by applying a combined balanced DEA-BSC approach. Data were collected from five organizations using questionnaires. The findings showed that only one of the five organizations examined was efficient, with 100% performance. This efficient organization had the ability to maintain its performance and balances among the BSC indices.

Using a case study on twenty branches of an Iranian bank, Khaki, Najafi, and Rashidi (2012) implemented the combined DEA-BSC model to differentiate between their performance. The applied model took into consideration financial indicators, such as profit margin and return on assets, along with nonfinancial indicators, such as customer satisfaction, advanced services, and employee skills. The proposed model comprised the four perspectives of the BSC – learning and growth, customer, internal, and financial perspectives – to identify the strengths and weaknesses within the performance of twenty different branches of the bank. Findings provide a benchmark scale to improve the performance of inefficient branches.

The objective of Lee (2012) study was to provide a comprehensive conceptual framework to integrate the BSC and DEA techniques for assessing management efficiency in the kitchen context. To meet this objective, data were collected from a family restaurant chain in South Korea. Three stores were chosen out of thirty-eight restaurants to obtain the BSC information. The selection of the stores was based on similarity, as they were operating under the same concept and offered the same menu. The findings support the usefulness of applying the DEA-BSC model as a decision-making tool. Furthermore, results showed the applicability of the BSC as a performance measurement technique to examine the efficiency level of the kitchens.

In spite of the difference in the applied context, the findings of Arabzad, Kamali, Naji, and Tavakoli (2013) and Kádárová et al. (2013) support the usefulness of applying the integrated DEA-BSC model. Whereas Arabzad et al. (2013) applied the integrated model to evaluate the performance of laboratory units of an Iran aircraft manufacturing industrial organization. Kádárová et al. (2013) developed a comprehensive model based on the DEA-BSC technique to assess the performance of five maintenance departments of a multinational industrial organization operating in vertical transportation. Kádárová used four models, as a DEA model has been developed for each BSC perspective. The organization that they investigated operates in the business of vertical transportation and was established in 2003.

The primary objective of Wang et al. (2013) was to propose a holistic framework for assessing organizational performance. To fulfil this objective, data were collected from seven publicly listed organizations in the tourism industry in Taiwan, covering the period from 2004 to 2008. The main contribution of this study is that it provides empirically support for the positive relationship between BSC and organizations' performance. Additionally, the study put forward significant recommendations for improving operational efficiency.

To assess the efficiency scores of food industries' supply chains in Iran, Shafiee, Lotfi, and Saleh (2014) applied a network DEA model in line with the BSC. Data were collected from twenty-two Iranian food supply chains for the year 2010. Based on the BSC perspectives, the network of supply chains was divided into four stages. Findings showed that managers pay more attention to customers, while they give less attention to learning and growth, and this reflects poor performance by the managers. The study provides a recommendation to solve this issue by providing educational workshops for employees.

During 2010, twenty-nine branches of the main Iranian Bank were evaluated and ranked. Shahroodi and Bahraloloom (2014) applied the DEA output-oriented model to evaluate the efficiency level of the bank branches. The applied model identified only eight branches as efficient, with efficiency scores of 1, whilst the remaining twenty-one branches were inefficient, with scores between 0 and 1. The study was limited by difficulty in collecting data for some BSC perspectives.

Wu and Liao (2014) developed a combined DEA-BSC model to assess the level of operational efficiency of airlines. They applied a cross-sectional research design to assess the performance of thirty-eight major airlines worldwide. Annual reports and business reports were used to obtain operational and financial data. The study contributes to the literature, by focusing not only on assessing efficiency scores but also taking into consideration how leading indicators can influence lagging indicators. The empirical findings indicated that efficient airlines tended to manage energy, capital, and other operating costs in a more optimal way.

To assess the efficiency of fifteen industrial co-operatives in Iran, Ehsanbakhsh and Izadikhah (2015) used an integrated fuzzy DEA-BSC model. In applying the DEA model, the input variables were the capacity of machines and the production-to-capacity ratio, whereas the output variables were annual profits, customer satisfaction and continuous improvement of productivity. The results indicated that only four of the fifteen units were efficient.

Haghighi, Torabi, and Ghasemi (2016) applied a combined DEA-BSC model to examine the sustainability performance of competing plastic recycling organizations. The study proposed to rank supply chains to find and benchmark the efficient units. To achieve this objective, data for forty plastic recycling organizations were collected using a questionnaire. The findings put forward a comprehensive framework for policymakers and top managers, which helps in improving sustainability performance in supply chain industries. Moreover, the study contributes to the literature by using a sample of plastic recycling organizations.

Likewise, from the sustainability viewpoint, Lin et al. (2016) evaluated technological and vocational higher education in Taiwan. The data required for the study were obtained from an expert questionnaire survey. The results of the study shed light on the usefulness of applying the integrated DEA-BSC model to evaluate sustainability performance in Taiwanese technological and vocational higher education institutions.

Kianfar, Ahadzadeh Namin, Alam Tabriz, Najafi, and Hosseinzadeh Lotfi (2016) applied the DEA-BSC model to assess the relative efficiency of twenty-one bank branches in Tehran. The findings demonstrate the appropriateness of applying the integrated model to improve the bank branches' efficiency level.

Zervopoulos, Brisimi, Emrouznejad, and Cheng (2016) collected data from thirty-six retail organizations operating in the US has been collected by to evaluate their performance by using DEA-BSC model. The study added value to the literature by taking into consideration the interrelationship between the indicators of each perspective of the BSC. The inputs used were operating and administrative expenses, number of employees, and number of stores, whilst the output was net sales. The results showed significant managerial consequences for the model proposed in the study, as it provides decision-makers with a production frontier that facilitates the benchmarking process.

To examine the performance of Taiwanese LED companies, Wang and Chien (2016) used the combined BSC and DEA model. They collected data for twenty-three Taiwanese LED companies for the period from 2010 to 2014. The inputs used were indirect costs, direct costs, and fixed assets, whilst the outputs were sales revenue, gross profit, and owner's equity. The findings proved that the proposed framework provides managerial insights to improve organizations' performance outcomes.

Asgari, Haeri, and Jafari (2017) utilized the DEA-BSC model to assess the performance of six Iranian banks. The BSC perspectives were used as the inputs and outputs of the DEA model. This study identified a new approach, which facilitates the selection of the appropriate indicators of each perspective of the BSC. The results showed that staff expertise and high-speed services are the most important variables for increasing banks' profitability. Another study conducted by Asgari, Haeri, and Jafari (2018) applied the DEA-BSC model to ten stations of the Tehran subway. The main purpose of the study was to provide guidelines for the appropriate selection of indicators. It provided significant recommendations for decision-makers in the transportation industry.

To assess the performance of nine European airlines, Dinçer et al. (2017) utilized the integrated BSC-DEA model. The findings indicated that the customer perspective is the most important one, whilst the learning and growth perspective had the lowest importance. Additionally, both customer and financial perspectives had a significant effect on the other perspectives, while the learning and growth perspective had no impact on the other perspectives. The study sheds light for airline organizations on the importance of efficiency and profitability as the most important variables for improving their performance.

Additionally, Tan et al. (2017) applied the integrated DEA-BSC model to evaluate the quality of the service provided by ten automobile dealers from various areas. They conducted a survey to collect the required data. The findings showed that the dealers were inefficient according to the customer perspective of the BSC, as they have no knowledge about customer growth. This study provided a guideline for dealers to enhance their performance and to increase customer satisfaction levels.

Basso et al. (2018) applied the combined two-stage DEA-BSC model to assess the performance of eleven municipal museums in Venice in the year 2013. All the museums selected for the study are managed by the Venice Municipal Museums Foundation, which provided the required financial and non-financial data. The empirical part was conducted in two main stages. First, the study built a BSC model for museums. Then, in order to calculate the efficiency score for each perspective of the BSC, an appropriate DEA model was chosen to be applied separately for each perspective. Second, the study applied a DEA model that combined the efficiency scores of the various BSC perspectives into an overall performance indicator.

The variables selected as inputs and outputs for each perspective are as follows. The input for the customer perspective is insured value and the outputs are the number of visitors, website visits, members, catalogues, and value of donations. The input for the financial perspective is expenditure and the outputs are income from tickets, sponsorships donations, public funding, and other incomes. For the innovation and learning perspective, the input is constant, and the output is personnel training (cost or number of hours per employee). For the internal process perspective, the input is total costs and outputs are conservation and restoration costs, the amount spent for new acquisitions, and the number of visitors. The study adopted the variable returns-to-scale approach. The findings of the empirical part of the study provided insights into the best practices, which are indicated for each dimension of the performance measurement process.

Using data from fifty-four service hotels in the United States, Dolasinski, Roberts, and Zheng (2018) applied the combined DAE-BSC model to evaluate the efficiency of a distribution channel mix. In other words, the study measures the efficiency of managing different booking channels to maximize hotel revenue. The data were collected from a multiunit hospitality company headquartered in the US. Inputs for the study were the channels of central reservations, global distribution systems, Brand.com, online travel agencies, and in-house sales, while the output was consolidated BSC results for each hotel. According to the DEA model used, an output-oriented constant return to scale (CRS) orientation was applied. The findings of the study determined four hotels with an optimal channel mix and fifty inefficient hotels. The study provides managers of the inefficient hotels with benchmark data to help in improving their efficiency level.

It can be notice in table 3.5 that previous studies which applied the integrated DEA-BSC model had different objectives. These different objectives have led researchers to choose different approaches for combining these two methods. Whilst some researchers have simply used the results of one method to feed into the results of the other, others have integrated the two methods. This integration has been carried out either through the use of a single DEA model with several outputs capturing the different performance dimensions, or through the use of multiple interconnected models (Amado et al., 2012).

Furthermore, Table 3.5 summarizes the major studies that have applied the combined DEA -BSC model by year of publication and shows that the combined model has been applied in different countries all over the world using a range of sample sizes. The table started with the study of Rouse et al. (2002), which shed light on the possibility of integrating the BSC with the DEA, until the studies published in 2018. The researcher found the following gaps in the previous studies: firstly, in spite of the vast number of studies in the literature review that examined the impact of applying the BSC or the DEA separately in improving the organizations performance assessment, few studies have addressed the impact of both techniques together. Secondly, the only study applied in the UK was conducted by Ramanathan and Ramanathan (2011), using a sample of ninety-four health authorities. Thirdly, the timeline of most studies was one year. Fourthly, only the study of Chiang and Lin (2009) applied the model to two different sub-sectors. Lastly, to the best of the researcher's knowledge, no study has applied cross industrial analysis.

Hence, in order to fill these gaps, the goal of the current study is to show that the integration of BSC and DEA can offer critical information and shed some light on the actions needed from decision-makers. Considering that BSC is a framework that tells the story of how each part of the organization contributes to its success by following a series of explicit cause-and-effect relationships, it is believed that it can offer a useful framework to structure several interconnected DEA models.

Table 3.5: A summary of major studies applied the integrated DEA -BSC model

Study	*Country*	*Period covered*	*Sample size & Context of application*	*Applied DEA model*	*Inputs used*	*Output used*	*Objectives of integrating DEA and BSC*
Rouse et al. (2002)	New Zealand	Four years (1993:1996)	Engineering division of an international airline	CCR model	“Salary cost and Inventory cost”	“Total hours charged and Delivery performance”	Developing performance monitoring system
Rickards (2003)	Europe	One year (2003)	Sixty-nine multinational organizations	BCC model	“Machine capacity, no. of employees, and advertising expenditure”	“Cash flow, customer commitment, internal service quality, and Employee motivation”	Evaluating overall management performance
Banker et al. (2004)	US	Five years (1993:1997)	Fifty local exchange carriers in the Telecommunications industry	BCC model	“Access lines per employee, Percentage of digital access Lines”	“ROA, Return on investments, and Return on capital”	Evaluating the trade-offs between different performance measures
Eilat et al. (2006)	Not clear	Not clear	Portfolios of R&D projects	CCR model	“Work content and material”	“Economic scientific, and social contributions”	Proposing a methodology for analysing portfolios of R&D
Chen and Chen (2007)	Taiwan	One year (2005)	Thirty Semiconductor manufacturers	CCR model	“Sales volume, Inventory turnover, Market share, and R&D Expense”	“Income rate before tax, ROA, Return on capital”	Examining the technical efficiency
Chen et al. (2008)	Taiwan	Five years (2001:2005)	Case study of Credit cooperative bank	CCR & BCC model	“Employee numbers, bank assets, interest expenses, bank deposits, and fixed assets”	“Bank loans, interest income and member households, and fee income”	Showing the consequences of selecting performance measures on performance results
Eilat et al. (2008)	Not clear	Not clear	Individual R&D projects	CCR model	Twenty-four output and input Measures	Twenty-four output and input measures	Assessing research and development projects within various stages

Min et al. (2008)	Korea	Three years (2002 :2004)	Six Luxury hotels	CCR model	"Cost of sales, labour, and other non-operating expenses"	"Revenue from rooms, food and beverage, and other services"	Comparing the efficiency levels
Chiang and Lin (2009)	US	One year	Thirty-nine Auto organizations and thirty commercial banks	CCR model	Employees, costs, materials, and assets	The four perspectives of the BSC	Evaluating performance in two distinct industries
García-Valderrama et al. (2009)	Spain	Three years (2002 :2004)	R&D activities in ninety chemical organizations	BCC model	The four perspectives of the BSC	The four perspectives of the BSC	Addressing the relationships between the various perspectives of the BSC
Macedo et al. (2009)	Brazil	One year	Bank branches	CCR model	Strategy indicators, internal processes; and organizational behaviour	"Indicators related to the perspectives of Economic Result; Costumers; Society"	Assessing bank branches efficiency scores
Asosheh et al. (2010)	Iran	One year	Three IT projects	CCR model	Resources Cost, Time, and Human resource	Indicators for the four perspectives of the BSC	Evaluating Ministry of Science, Research and Technology
Roodposhti et al. (2010)	Iran	One year	Six Commercial banks	BCC model	Income ratio, competitive pricing, electronic services, and expenses	Capital growth rate, customer satisfaction, advanced services, and personal skills	Ranking of 6 banks based on their efficiency levels
Lu and Chen (2011)	Taiwan	One year (2006)	Twenty-eight Military financial Bureaus	CCR model	Four indicators of each BSC perspectives	The four perspectives of the BSC	Evaluating the techniques used in assessing the military financial units
Ramanathan and Ramanathan (2011)	UK	One year	Ninety-four health authorities	CCR model	Thirty-two inputs	Twenty-five outputs	Evaluating the performance of health authorities in the UK
Alvandi and AzamMasoumi (2012)	Iran	One year	Five Automotive and Spare Parts Organizations	BCC model	Human resources, fixed capital, and raw material	The four perspectives of the BSC	Determining the inefficient organizations and providing guidelines for improving their performance

Khaki et al. (2012)	Iran	One year	Twenty bank branches	CCR model	Unpaid loans, Fast and reliable services, and expenses	Profit margin Customer satisfaction, and employees' skills	Comparing performance of 20 units of banks
Lee (2012)	South Korea	One year (2009)	Three Family restaurants	CCR model	Nine input variables	Six output variables	Evaluating management efficiency in the kitchen areas
Arabzad et al. (2013)	Iran	One year	Eight laboratory units of an aircraft organization	CCR model	Sales growth, new customers, hours of training, and work time	The four perspectives of the BSC	Evaluating the performance of laboratory units
Kádárová et al. (2013)	Slovak Republic	One year (2011)	Five maintenance departments of a multinational organization operating in transportation	CCR model	Ten indicators had been used as inputs for four different DEA models	The four perspectives of the BSC	Assessing the performance of the Maintenance Departments
Wang et al. (2013)	Taiwan	Five years (2004 :2008)	Seven publicly listed organizations in the tourism industry	CCR & BCC model	Indicators of the BSC perspectives financial, customer, internal process, and the learning and growth	Operation ROA and ROE, Profitability, Organization Value, and Stock Return.	Proposing a holistic framework for assessing organization performance
Shafiee et al. (2014)	Iran	One year (2010)	Twenty-two supply chains in food industries	network DEA	The four perspectives of the BSC	The four perspectives of the BSC	Appraising the efficiency of supply chains
Shahroodi and Bahraloloom (2014)	Iran	One year (2010)	Twenty-nine bank branches	CCR model	Training, experience, commission, and facilities	Customer Satisfaction, Market, income, and ROA	Ranking Bank branches during 2010
Wu and Liao (2014)	Different countries	One year (2012)	Thirty-eight major airlines worldwide	CCR model	No. of passengers, Energy, capital, material costs, other operating expense per employee	Operating revenue, Return on investment, Return on assets, and Net income	Evaluating the operational efficiency of airlines

Ehsanbakhsh and Izadikhah (2015)	Iran	One year	Fifteen industrial co-operatives	CCR model	The capacity of machines and production to capacity ratio	profits, customer satisfaction and continuous improvement of productivity	Assessing the efficiency levels
Haghighi et al. (2016)	Iran	One year	Forty plastic recycling organizations	Network DEA	Delivery cost, number of green products, Time delivery, and customers' satisfaction	The four perspectives of the BSC	Examining the sustainability performance
Kianfar et al. (2016)	Iran	One year	Twenty-one bank branches	CCR & BCC model	Profit margin, customer satisfaction, speed of service, and expertise of employees	The four perspectives of the BSC	Assessing the relative efficiency
Zervopoulos et al. (2016)	US	One year	Thirty-six retail organizations	Network DEA	Operating and administrative expenses, number of employees, and number of stores	Net sales	Facilitating the benchmarking process.
Wang and Chien (2016)	Taiwan	Five years (2010 :2014)	Twenty-three LED companies	CCR & BCC model	Indirect costs, direct costs, and fixed assets.	Sale revenue, gross profit, and owner's equity	Examine the performance of Taiwanese LED companies
Asgari et al. (2017)	Iran	One year	Six banks	Three stage DEA model	Incentive fee, increased staff expertise, customer satisfaction, and customer attraction rate	Advanced services, high-speed services, and profit margin	Evaluating the performance efficiency level
Dinçer et al. (2017)	Europe	One year	Nine European airlines	Fuzzy DEA	The four perspectives of the BSC	The four perspectives of the BSC	Assessing the performance efficiency scores
Tan et al. (2017)	US	One year (2012)	Ten automobile dealers	CCR model	Physical aspects, Customer relationship, Policy, and Problem solving	no. of customers, serviced daily, Profit, Order processing time, and Complaints	Improving performance and increasing customer satisfaction levels

Asgari et al. (2018)	Iran	One year	Ten urban railway stations	Three stage DEA model	Staff's knowledge level, average density per passengers, waiting at station, and delay per trip	Efficiency of train, number of delayed trips, labour costs, and labour costs per each trip	Providing guidelines for selecting the right indicators
Basso et al. (2018)	Italy	One year (2013)	Eleven municipal museums in Venice	Two stage DEA model with VRS	Insured value, total costs, expenditure	Number of visitors, web site visits, members, catalogues, (value of) donations, number of visitors, Personnel training, and Income	Evaluating the performance of 11 municipal museums of Venice
Dolasinski et al. (2018)	US	One year	Fifty-four service hotels	CRS model	Channels of central reservations, global distribution systems, Brand.com, online travel agencies, and In-house sales.	consolidated BSC results for each hotel	Measuring the efficiency of hotel channel mix

Source: Prepared by the Researcher

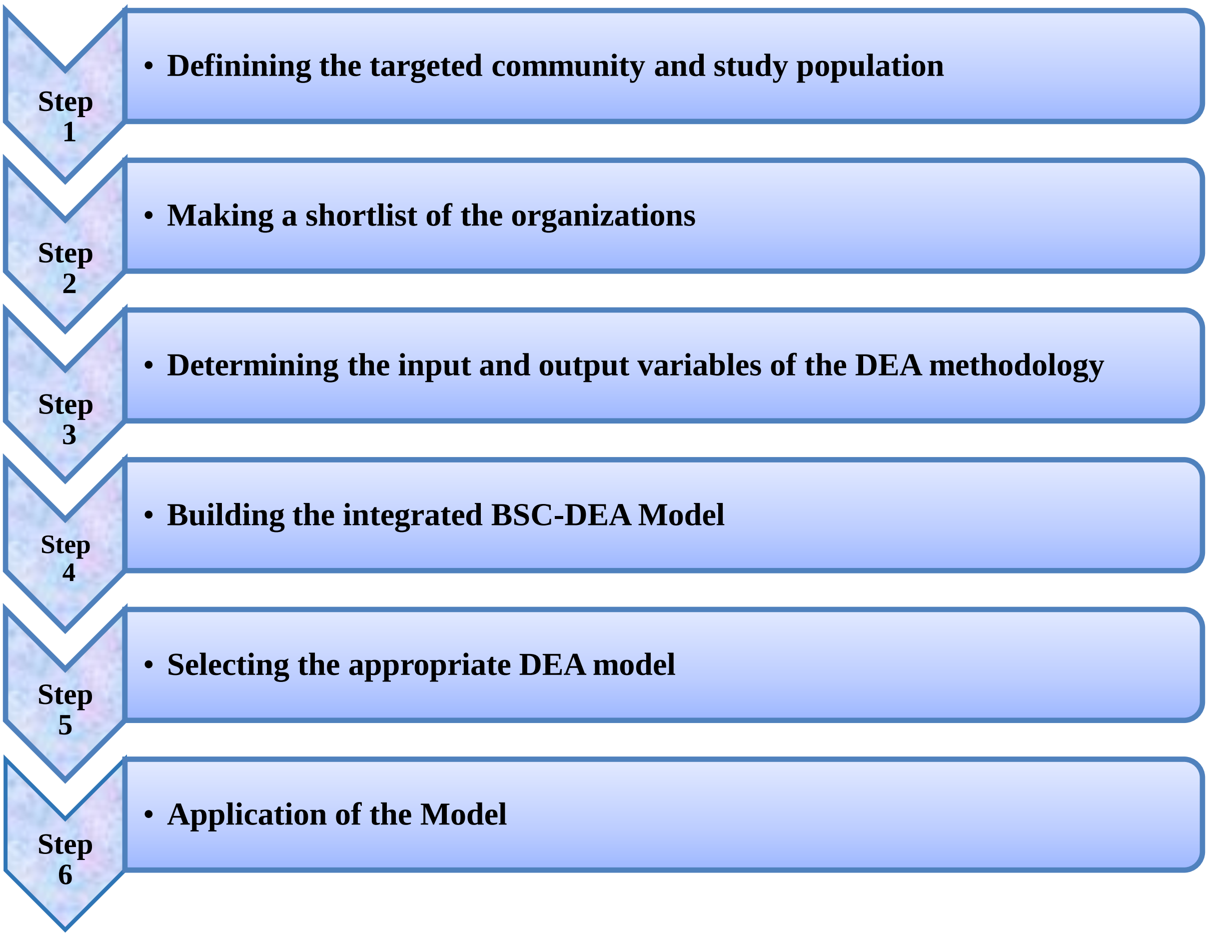
Chapter Four: Research Method

4.1 Introduction

This chapter discusses the research method adopted for the present study and builds the research design to empirically investigate the impact of applying the combined DEA-BSC model on improving organizations' performance assessment. It presents the design of the research, showing the steps followed, which include data collection, the selection of variables, the DEA model that will be used, and finally the building of the combined DEA-BSC model.

The research design includes strategies, choices, time horizons, and techniques and other procedures followed, as will be discussed in detail in the following section. In terms of research strategy, this study can be classified as "Action research" concerned with solving a particular problem, as it is trying to mitigate the problems associated with performance assessment techniques by providing a combined DEA-BSC model. The research design for this thesis consisted of six steps, as presented in Figure 4.1.

Figure 4.1: Research Design Steps



Source: Prepared by the Researcher

4.2 Study Population and sample selection

The targeted population of the study is all organizations traded on the London Stock Exchange and included in the FTSE All-Share Index. In order to provide a comprehensive view for the organizations' performance, the time frame for the data collection is five years from 2012 to 2016, which is the longest period that had been adopted in other previous studies (Banker, Chang, Janakiraman, & Konstans, 2004; Chen, Chen, & Peng, 2008; Wang & Chien, 2016; Wang, Li, Jan, & Chang, 2013).The organizations have been classified based on the Industry Classification Benchmark (ICB), which is defined on the Wikipedia website as "an industry classification taxonomy launched by Dow Jones and FTSE in 2005 and now owned solely by FTSE International. It is used to segregate markets into sectors within the macroeconomy. The ICB uses a system of 10 industries, partitioned into 19 supersectors, which are further divided into 41 sectors, which then contain 114 subsectors". Table 4.1 shows the number of organizations included in the current study, which have been categorized based on ICB different industries and sectors.

Table 4.1: Summary of different industries of the study

Industry	**No. of organizations**	**Sector**
1- Industrials	100	• Construction & Materials • General Industrials • Aerospace & Defence • Electronic & Electrical Equipment • Industrial Engineering • Industrial Transportation • Support Services
2- Consumer Services	87	• Food & Drug Retailers • General Retailers • Media • Travel & Leisure
3- Consumer Goods	42	• Household Goods & Home Construction • Leisure Goods • Personal Goods • Tobacco
4- Basic Materials	26	• Chemicals • Forestry & Paper • Industrial Metals & Mining • Mining

5- Health Care	19	• Health Care Equipment & Services • Pharmaceuticals & Biotechnology
6- Oil & Gas	17	• Oil & Gas Producers • Oil Equipment, Services & Distribution • Alternative Energy
7- Technology	16	• Software & Computer Services • Technology Hardware & Equipment
➢ Total organizations = 307		

Source: Prepared by the Researcher

Accordingly, the current study includes organizations from various sectors and industries, as shown in Table 4.1. Organizations selected in this study are determined based on the following criteria: first, the availability of financial data over five years starting in 2012 and ending in 2016; second, the availability of information about the other three non-financial perspectives of the BSC, namely the customer, internal process, and learning and growth perspectives. However, the current study excludes the "financials" industry, which includes banks, insurance, real estate, and financial services, due to their different nature from other sectors. In order to apply the DEA appropriately, all DMUs included and data utilized should be homogeneous (Serrano-Cinca et al., 2005).

4.3 Data Sources/Collection

In order to examine the applicability of the combined DEA-BSC model in various industries, secondary data was obtained from the "DataStream" database. All of the data utilized in the current study are obtained from the financial statements of each organization. Smith (2008) stated that "Secondary data is data that has been previously prepared for a specific study or purpose by someone other than the researcher and is being repurposed for other uses, including additional research. The rationales for using secondary data are the access to data at a much larger scale than may be possible by the researcher and access to data not easily replicable by the researcher" (p.324).

Hsu et al. (2013) obtained the data required for their analysis from only one source, namely shareholder reports. The author justified the use of only secondary data as follows: "The use of shareholder reports as the sole source of data does not allow us to provide a comprehensive BSC reflecting measures related to the four dimensions. A more comprehensive BSC would require access to internal corporate data on operations and strategy, and we expect that to be the focus of studies that follow this one" (p.138). Additionally, some of the data required access to the internal details for the organizations that will be assessed.

According to the DEA technique, the data set used is considered as the entire population. Every organization included in the analysis is named as a Decision-Making Unit (DMU). Although there are no definite rules to determine the optimal and appropriate number of DMUs that should be included in the analysis, the general guideline or consensus states that the number of DMUs should be at least double the combination of input and output variables (Golany & Roll, 1989). Hence, by applying this guideline, both the utilities and telecommunications industries will be excluded, as they have seven and six organizations respectively. Consequently, the final data set used for the current study consists of 307 organizations for a period of five years from 2012 to 2016, leading to 1535 organization-year observations. Table 4.1 provides the number of organizations that have been included in each industry and which have available data for the required time series.

4.4 Selection of input and output variables

Thanassoulis (1996) stated that the DEA is a non-parametric approach which depends on transforming inputs into outputs in order to determine the optimum amount of both inputs and outputs (maximum output produced using a given amount of inputs or the minimum input amounts required to produce a given output amount). Accordingly, determining appropriate inputs and outputs plays a vital role in the correct application of the DEA technique. Furthermore, as stated by Amado et al. (2012), the selection of variables is based mainly on the availability of reliable data.

As the current study applied the combined DEA-BSC model, the variables – both inputs and outputs – will be extracted using the BSC framework. Avkiran (2006) mentioned that there are two approaches for choosing variables. The first approach is from the academic point of view, which is based mainly on reviewing the literature. The other approach is from the managerial point of view and focuses on choosing variables that will represent the analysis, provide insight for the managers of the organizations and help in determining the key success factors of the organization.

The current study tried to apply the two approaches. Hence, after reviewing the literature and with respect to data availability, Table 4.2 presents a summary of the inputs and outputs adopted in the study and the codes for each variable that have been used to facilitate discussion of the results. The current study used four factors as input variables for the input measurement, including number of employees (Manasakis et al., 2013), total operating expenses (Hsu et al., 2013; Manasakis et al., 2013), total assets (Hsu et al., 2013), and total capital. For the output measurement, the study includes the four major perspectives of the BSC. To measure these four perspectives, various indicators have been suggested in the literature. As the current study depends only on secondary data, in terms of financial perspective, operating income (Hsu et al., 2013) and net income (Hsu et al., 2013) are adopted. From the customer perspective, sales volume (Manasakis et al., 2013) and relative market share are used, whereas the indicators of the internal process perspective are total assets turnover (Hsu et al., 2013) and outstanding shares. The learning and growth perspective's indicators are intangible assets (Hsu et al., 2013) and profit per employee.

Consequently, given four inputs and four outputs, applying the rule of thumb suggested by Cooper et al. (2007), which states that the minimum number of analysed DMUs = (no. of inputs + no. of outputs) × two, resulted in a minimum of 16 DMUs. Fernandes et al. (2018) state that "if this rule does not hold, then a large number of DMUs might be found efficient. However, the lack of degrees of freedom is likely to make the efficiency discrimination questionable" (p.286). Consequently, the researcher limits the number of used variables in order to include all the industries; however, both the utilities and telecommunications industries will be excluded, as they have limited numbers of organizations, at seven and six organizations respectively.

Table 4.2: Summary of variables adopted

Category	Name	Code
Input	• Number of employees • Total operating expenses • Total assets • Total capital	• NE • TOE • TA • TC
Output	• Financial perspective: - Operating income - Net income • Customer perspective: - Net Sales - Relative market share • Internal process perspective: - Total assets turnover - Common shares outstanding • Learning and growth perspective: - Total intangible assets - Profit per employee	• Financial perspective: - OI - NI • Customer perspective: - NS - RMS • Internal process perspective: - TAT - CSO • Learning and growth perspective: - TIA - PPEM

Source: Prepared by the Researcher

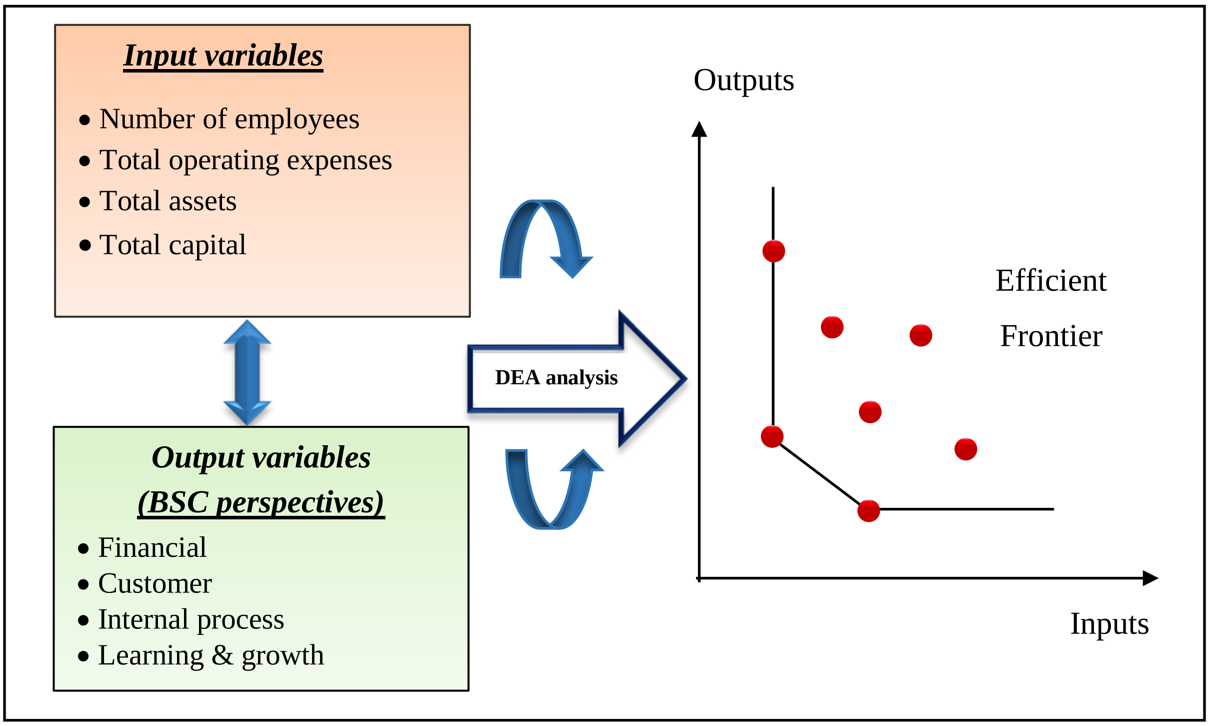
The current study selected the input and output based on the following criteria; firstly, variables that will fit into the different industries included in the analysis. Secondly, the most frequently used in the literature. Thirdly, the data availability of these variables for the five years considered in the analysis.

4.5 The combined DEA-BSC model

The objective of the study is to assess the performance of seven different industries (i.e., Industrials, Consumer Goods, Consumer Services, Basic Materials, Oil & Gas, Health Care, and Technology) by applying BSC and DEA. Specific steps must be followed to implement the combined DEA-BSC model.

The first step is to determine the targets and strategies of each organization. Then the BSC determines the indicators required to measure each perspective. The second step is to conduct the performance evaluation, where the selected indicators of the BSC will be categorized into inputs and outputs in order to implement the DEA technique. Thirdly, by using the DEA, the potential improvements can be determined for each organization included in the analysis. Finally, benchmarks are set for the following performance evaluation process and recommendations are provided for future improvements (Najafi et al., 2009).

Figure 4.2: The study's combined DEA- BSC model



Source: Prepared by the Researcher

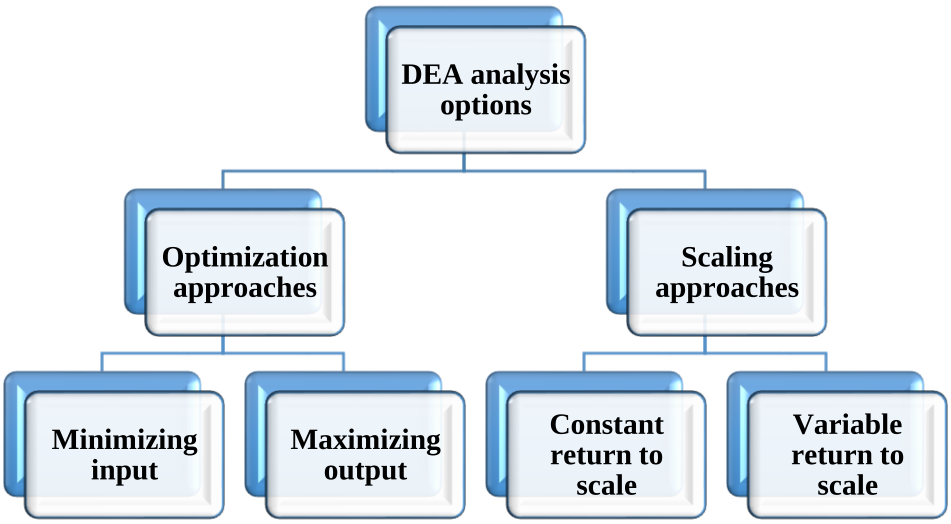
The software used to run the combined DEA-BSC model for the current study is Frontier Analyst. DEA software programs are available in both commercial and non-commercial offers. The software applied in the current study has been provided by www.banxia.com, Frontier Analyst software version 4.3.

As shown in Figure 4.2, applying the combined DEA-BSC model provides managers with a comprehensive framework. Managers must apply the BSC to examine the performance of their organizations from both financial and non-financial perspectives. Additionally, managers need to apply the DEA technique to assess the competitiveness of their organizations and to determine sources of inefficiency, benchmarking peers, and potential improvements.

4.6 Selection of DEA model

As presented in Figure 4.3, in applying the DEA technique, there are two main analysis options, namely the optimization method and the nature of the returns to scale for each DMU. The DEA has been defined as a linear programming-based technique for evaluating organizations' levels of performance efficiency. Hence, the optimization method is the objective function of the linear program. The optimization method can be either input minimization oriented or output maximization oriented.

Figure 4.3: DEA analysis options



Source: Prepared by the Researcher

The objective of the input minimization orientation is to produce the same level of outputs while minimizing inputs. This option attracts the attention of the analyst when the case is related to cost-reduction strategies. In contrast, the objective of the output maximization orientation is to maximize the outputs produced with the same level of inputs. The output maximization option is suitable when the target of the organization is to increase productivity using the same amount of resources. Banker et al. (1984) stated that “the output-oriented model provides an indication of the capacity shortfall and encourages a more strategic approach to improving efficiency as opposed to the often-blunt instrument approach of reducing inputs” (p.1079).

Given the nature of the returns to scale for each DMU, there are two available choices, namely constant returns to scale, provided by the CCR model, and variable returns to scale, provided by the BCC model. Although the most commonly used option in articles published on the DEA since the 1980s is the constant returns to scale, this is only suitable when most of the DMUs in the analysis are operating at the most productive scale size: in other words, it is applicable in analysing a homogenous group of DMUs.

Constant returns to scale are based on the assumption that outputs change in direct proportion to the change in inputs, regardless of the size of the DMU. Whilst the CCR model evaluates overall efficiency, this model includes both pure technical efficiency and pure scale efficiency. Pure technical efficiency examines managerial efficiency, while scale efficiency examines whether or not the organization is operating optimally for its size. The CCR model is based on the assumption that an increase in inputs results in the same level of increase in outputs. For instance, it is assumed that if the inputs are doubled, then the outputs are also expected to double. The BCC model is able to differentiate between pure technical efficiency and scale efficiency.

Additionally, Avkiran (2006) stated that in spite of the fact that constant returns to scale is a good indicator of general efficiency, the potential improvements provided by the CCR are doubted and still leave inefficiency in the system. These remaining inefficiencies may be determined more explicitly by applying the BCC model to identify pure technical inefficiencies and the CCR/BCC ratio to identify pure scale inefficiencies. Furthermore, in terms of providing policy recommendations, it is better to apply the BCC model rather than the CCR model.

On the other hand, given that the present study involves a large sample with a considerable variation in the size of the DMUs, the appropriate scaling mode is the variable returns to scale. This is based on the assumption that changing inputs will not result in a proportional change in outputs. Given the large sample size and the varying nature of the targeted organizations in the current study, the researcher will apply the variable returns to scale and the output maximization option.

4.7 Summary

This chapter has discussed the research methods been applied in this research. Furthermore, it has provided justifications for the selection of each method used. The research design includes data selection procedures, the construction of the combined DEA-BSC model, and how the model is applied to the data. Table 4.3 summarizes the main perspectives of the current research methodology and design, as discussed above. It shows that the current research is a descriptive study and is based mainly on secondary data (quantitative) and that its results are based on facts or observable phenomena, not on assumptions. Additionally, the research is based on quantitative data collection. The final data set used for the current study consists of 307 organizations covering a period of five years, from 2012 to 2016. According to the DEA techniques, the output maximization approach will be followed, with variable return to scale.

Table 4.3: Summary of research methodology and design

Classification of research	
Classification of research	Descriptive study
Research Strategy	
Research strategy	Action research
Qualitative or Quantitative methodology	
Quantitative	Quantitative Procedures
Primary and Secondary Data	
Secondary Data	Literature Review Financial statements
Data type	
Longitudinal	Panel data
Research time horizon	2012:2016
Industry	Cross-industrial
DEA models	
Optimization method	Output maximization
Returns to scale	Variable returns to scale

Source: Prepared by the Researcher

Chapter Five: Data Analysis and Research Results

5.1 Introduction

To achieve the objective of the current research and answer the research questions, Frontier Analyst software version 4.3 was applied to analyse the data. This chapter presents the results from applying the combined DEA-BSC to various organizations within seven different industries and identifies the optimal combination of variables. As mentioned in Chapter 4, the variable returns to scale with output maximization approach has been used to calculate the different types of efficiencies.

Within the DEA model, the organizations' efficiency score results are categorized into three groups: 1) organizations that achieve 100% efficiency scores; 2) organizations that achieve above-average efficiency scores (between 90% and 100%); and 3) organizations that achieve below-average efficiency scores (less than 90%). The rest of this chapter includes seven sections, each of which discusses the results for a different industry

5.2 Technology Industry

The technology industry includes sixteen organizations from two sectors, namely Software and Computer Services and Technology Hardware and Equipment. The list of organizations' names, codes, and sectors adopted in the analysis of the technological industry are included in Appendix A, Table A.1.

5.2.1 BCC Model – Technical Efficiency

The BCC model examines managerial efficiency, or in other words, it evaluates pure technical efficiency. In contrast to the CCR model, the BCC model supports variable returns to scale. This means that if there is an increase in inputs, this does not necessarily result in the same level of increase in outputs.

5.2.1.1 Model Validation

One significant advantage of DEA is providing potential improvements for each inefficient organization. DEA provides a target value for each variable. Hence, inefficient organizations need to achieve these targets in order to obtain 100% efficiency scores. To check the validity of the applied BCC model, each model was operated with the target variables substituted in place of the actual variables. Table 5.1 presents the results of the BCC validation model. In each of the sixteen model runs, the substituted variables return an efficiency score of 100%, as expected. These results validate both the model and the target variables.

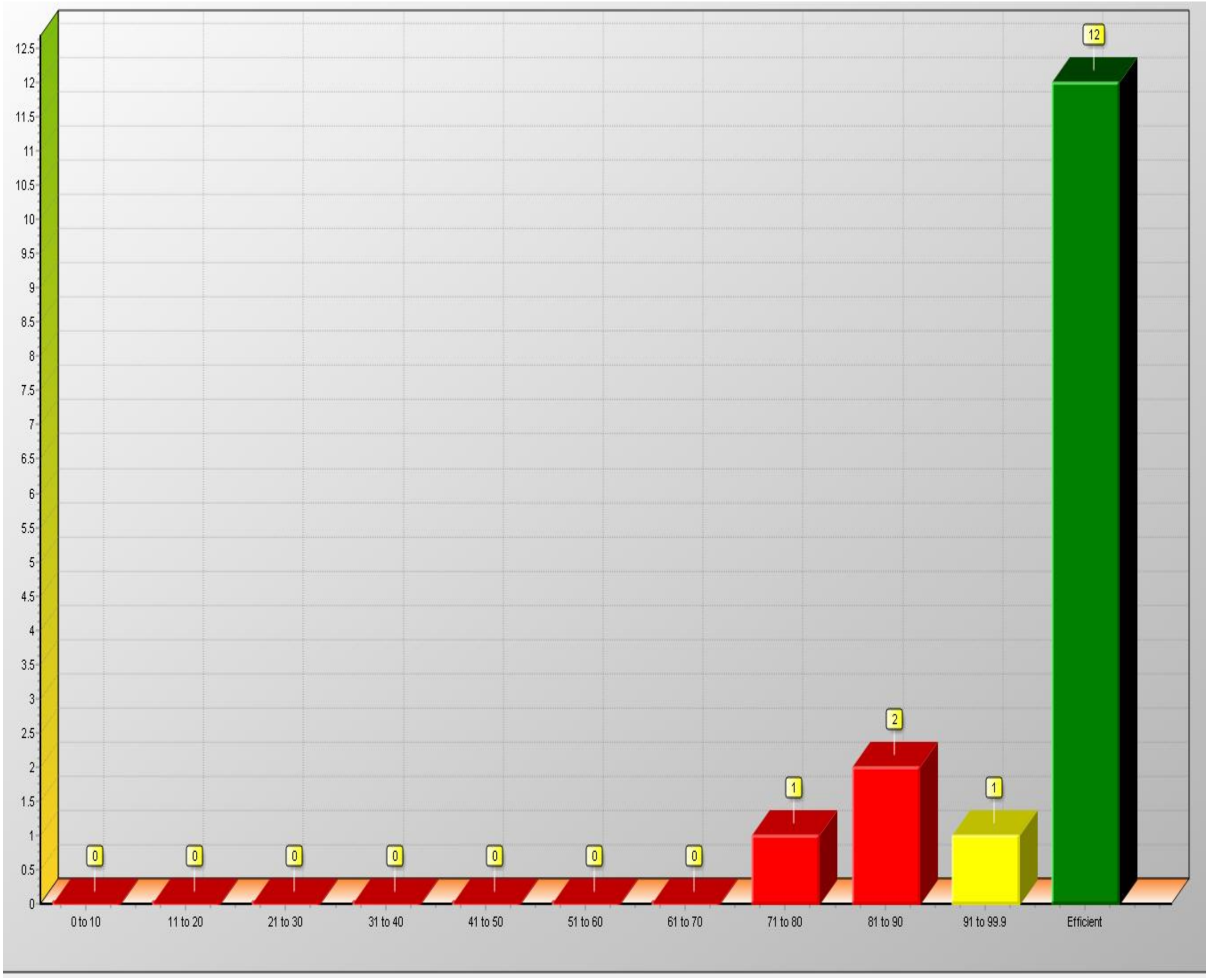
Table 5.1: BCC Model Validation Results for technology industry at 2016

No.	DMU	BCC model actual Result %	Target NE	Target TOE	Target TA	Target TC	Target OI	Target NI	Target NS	Target RMS	Target TAT	Target CSO	Target TIA	Target PPEM	BCC model validation Result %
1	CCC	100	13373	3159728	1230095	429799	85669	63773	3245397	0.08	2.64	122688	76285	4.77	100
2	FDM	100	3170	153982	81552	53338	35421	26182	189403	0	2.32	107518	19533	8.26	100
3	FDSA	100	1736	317190	294319	165077	14745	35754	331935	0.01	1.13	38585	93465	20.6	100
4	KNOS	100	733	63059	42005	25923	13535	12427	76594	0	1.82	117995	93465	16.95	100
5	MCRO	100	4287	616680	3034864	2115768	215835	108921	832514	0.02	0.27	228676	2327463	25.41	100
6	NANO	100	129	13539	22417	18763	-13065	-10607	1474	0	0.02	237065	2423	-82.22	100
7	NCC	100	1402	178701	398035	296320	30401	6283	209102	0.01	0.53	275823	297277	4.48	100
8	SCT	100	927	626488	206817	87364	45863	33158	672351	0.02	3.25	197406	6617	35.77	100
9	SERV	100	620	49974	108273	69728	10983	7699	60957	0	0.56	69448	69338	12.42	100
10	SGE	100	13741	1160900	2597900	1587700	408200	207600	1569100	0.04	0.6	1079958	1767800	15.11	100
11	SOPH	100	2699	312445	694330	313478	5993	-47879	318438	0.01	0.46	452172	526594	-17.74	100
12	SPT	100	1599	316185	385631	277038	24396	-31462	340581	0.01	0.88	611700	137708	-19.68	100
13	AVV	92.28	1703	172067	293453	184438.1	46283.44	28717.09	218350.4	0.01	1.76	188506.5	257397.8	17.76	100
14	SDL	88.19	3038	242400	269500	163346.1	57736.36	36265.98	300136.4	0.01	2.12	191450.5	172235.4	13.74	100
15	LRD	85.53	6555	756900	1148200	678862.8	180320.6	96569.81	937220.6	0.02	1.65	516421.4	742550.9	19.24	100
16	IMG	77.98	980	155094	212868.7	132841	6144.01	-16423.8	161625.3	0	0.7	354750.6	117279.4	-36.41	100

5.2.1.2 Efficiency scores

Based on the BCC model in Table 5.1, Figure 5.1 presents the technical efficiency scores and rankings for the sixteen organizations from the technology industry. The graph shows that twelve organizations out of sixteen are efficient and obtain 100% efficiency scores. These organizations are CCC, FDM, FDSA, KNOS, MCRO, NANO, NCC, SCT, SERV, SGE, SOPH, and SPT. The efficiency scores provided are relative and not absolute.

Figure 5.1: Distribution of efficiency scores for technology industry in 2016



The BCC model measures only managerial efficiency. It shows that from this perspective, the performance of the majority of the technological organizations is efficient. As shown in Table 5.2, about 75% of the organizations analysed are technically efficient. This indicates that the managerial teams have a significant role and a positive impact on the overall efficiency of their organizations. The implication of this is that there are greater efficiencies to be achieved in other areas: i.e. scale efficiencies.

Table 5.2: Efficiency score categories for the technology industry in 2016

Efficiency score categories	**Number**	**Percentage**
Efficient (Equal to 100%)	12	75 %
Above average (Less than 100% and ≤ 90%)	1	6%
Below average (Less than 90%)	3	19%
Total	16	100%

Additionally, as shown in Table 5.1, three organizations are performing below average, with scores of 88.19%, 85.53%, and 77.98%: these organizations are SDL, LRD, and IMG respectively. The only organization that is categorized as performing above the average is AVV, with an efficiency score of 92.28%.

5.2.1.3 Return to scale

Table 5.3 shows technical efficiency, decomposed into pure technical efficiency and scale efficiency. Technical efficiency scores are obtained from a CRS run, whereas pure technical efficiency scores are generated through a VRS run. The last column identifies the returns to scale prevailing in each DMU at the time of measurement. An organization is considered to be scale efficient when the size of its operation is optimal and any change to its size will result in a reduction in efficiency.

Table 5.3: Returns to Scale for technology industry in 2016

NO	**DMU**	**Technical Efficiency %**	**Pure Technical Efficiency %**	**Scale Efficiency %**	**Returns to Scale**
1	AVV	91.71	92.28	99.38	Decreasing returns
2	CCC	99.89	100	99.89	Increasing returns
3	FDM	100	100	100	Constant
4	FDSA	99.16	100	99.16	Increasing returns
5	IMG	71.3	77.98	91.43	Increasing returns
6	KNOS	100	100	100	Constant
7	LRD	81.93	85.53	95.79	Increasing returns
8	MCRO	100	100	100	Constant
9	NANO	100	100	100	Constant
10	NCC	97.83	100	97.83	Increasing returns
11	SCT	100	100	100	Constant
12	SDL	86.47	88.19	98.05	Increasing returns
13	SERV	99.49	100	99.49	Decreasing returns
14	SGE	100	100	100	Constant
15	SOPH	98.95	100	98.95	Increasing returns
16	SPT	100	100	100	Constant

It can be clearly seen that decomposing technical efficiency scores into pure technical efficiency and scale efficiency reveals that only seven of the sixteen organizations are operating at their most productive scale size, with the remainder being distributed between increasing and decreasing returns to scale. Another seven organizations are obtaining increasing returns to scale, which means that those organizations should consider expanding the scale of their operations in order to benefit from higher productivity. Furthermore, the two organizations (AVV and SERV) which obtain decreasing returns to scale should consider downsizing. Banker (1984) stated that in the case of decreasing returns to scale, an increase in inputs leads to a less than proportionate increase in outputs.

5.2.1.4 Potential improvements

The potential improvement determines the areas on which management should expect to spend most of its efforts. Once inefficient organizations have been determined, appropriate measures and actions can be taken to enhance their performance. As well as helping managers to measure their organizations' performance and determine best practice, DEA also provides the potential improvements that the inefficient organizations can follow to be efficient. Since the most efficient organizations are operating in the same environment, inefficient organizations could enhance their performance by choosing the same policies and managerial structures as their respective peer (reference) organizations.

For the efficient organizations, there are no changes to the actual values of their variables. Hence, Table 5.4 shows the potential improvements for each inefficient organization. Additionally, the table represents the reference set for each unit. Sherman and Gold (1985) stated that DEA groups DMUs as either efficient or inefficient compared to its reference set. The reference set of a unit consists of efficient units most similar to that unit in their levels of inputs and outputs.

Table 5.4: Potential improvements in the technology industry in 2016

Category	Variable	AVV (Efficiency: 92.2%)	SDL (Efficiency: 88.1%)	LRD (Efficiency: 85.5%)	IMG (Efficiency: 77.9%)
Input	NE	0.00%	0.00%	0.00%	0.00%
	TOE	0.00%	0.00%	0.00%	0.00%
	TA	0.00%	0.00%	0.00%	0.00%
	TC	0.00%	0.00%	0.00%	0.00%
Financial	OI	57.30%	158.91%	303.40%	120.92%
	NI	40.26%	300.36%	925.38%	79.69%
customer	NS	8.37%	13.39%	16.92%	28.55%
	RMS	8.37%	13.39%	16.92%	28.24%
Internal process	TAT	156.07%	115.99%	136.48%	34.70%
	CSO	194.72%	134.91%	46.53%	28.24%
Learning and growth	TIA	236.30%	13.39%	16.92%	28.24%
	PPEM	47.69%	371.68%	269.45%	35.65%
	Reference set	KNOS, MCRO, SCT, and SGE,	FDM, KNOS, SCT, and SGE	CCC, KNOS, SCT, and SGE,	KNOS, NANO, SCT, SOPH, and SPT

It can be clearly seen that both the financial perspective (operating income, net income) and the learning and growth perspective (profit per employee, total intangible assets) are playing a dominant role in the potential improvements provided by the DEA, followed by the internal process perspective (total assets turnover, common outstanding shares). The customer perspective has the least impact. For instance, according to the most inefficient (IMG) organization, which achieves a 77.9% efficiency score, DEA indicates a potential increase in the operating income by 120%, followed by an increase in both net income and profit per employee by 79.69% and 35.65% respectively. The same situation is found in SDL and LRD, with efficiency scores of 88.1% and 85.5% respectively.

For AVV, which is considered to be have above-average performance, with an efficiency score of 92.2%, the potential improvements that have been suggested show that the learning and growth perspective variables are the most important, followed by the internal process perspective variables and then financial perspective variables.

5.2.1.5 Reference (Peer) Groups

Avkiran (2006) defined the reference group as "The reference set of an inefficient unit consists of efficient units most similar to that unit in their levels of inputs and outputs" (p.280). For each inefficient DMU, DEA determines a group of corresponding efficient organizations, which are named the peer group or reference group. This set consists of organizations (DMUs) which are characterized by operating methods similar to the inefficient one being examined and provides a realistic term of comparison, which the inefficient organization should aim to simulate in order to enhance its performance (Rezaeiani & Foroughi, 2018). The process of determining the efficient units that are of similar configuration to the inefficient unit examined is called *"Reference Comparison"*.

Furthermore, "*reference set frequency*" can be applied in order to determine which of the units in the sample can be considered the overall best performer (also known as the global leader). Chen and Yeh (1998) stated that the efficient unit that appears in reference sets most frequently becomes the global leader. Chen (1997) argued that "the frequency of the reference set could be used as an indicator of the robustness of an efficient organization relative to its efficient peers" (p.44).

Similarly, Avkiran (2006) mentioned that "the more frequently an efficient organization is identified as a role model for inefficient organizations, the more robust it is. These organizations which appear frequently in the reference set of the inefficient organizations are likely to be efficient across a range of factors, making them good examples to emulate. Conversely, efficient organizations which appear infrequently in the reference set of the inefficient organizations are not as robust and therefore not suitable for emulation. This means that they are highly sensitive to small changes in their input and output variables and therefore their position on the frontier is tenuous" (p.280).

Figure 5.2: Reference Set Frequency for technology industry in 2016

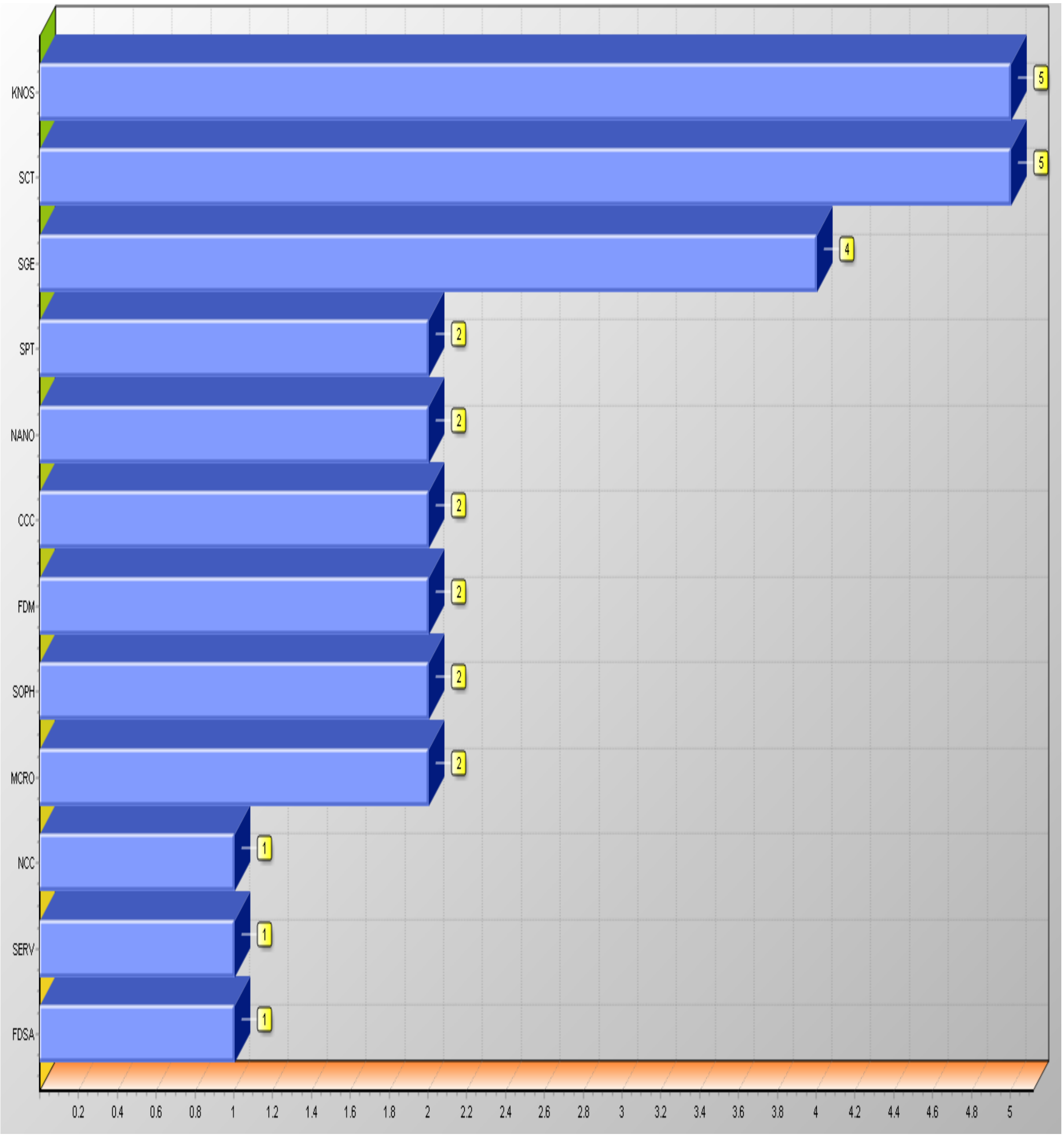
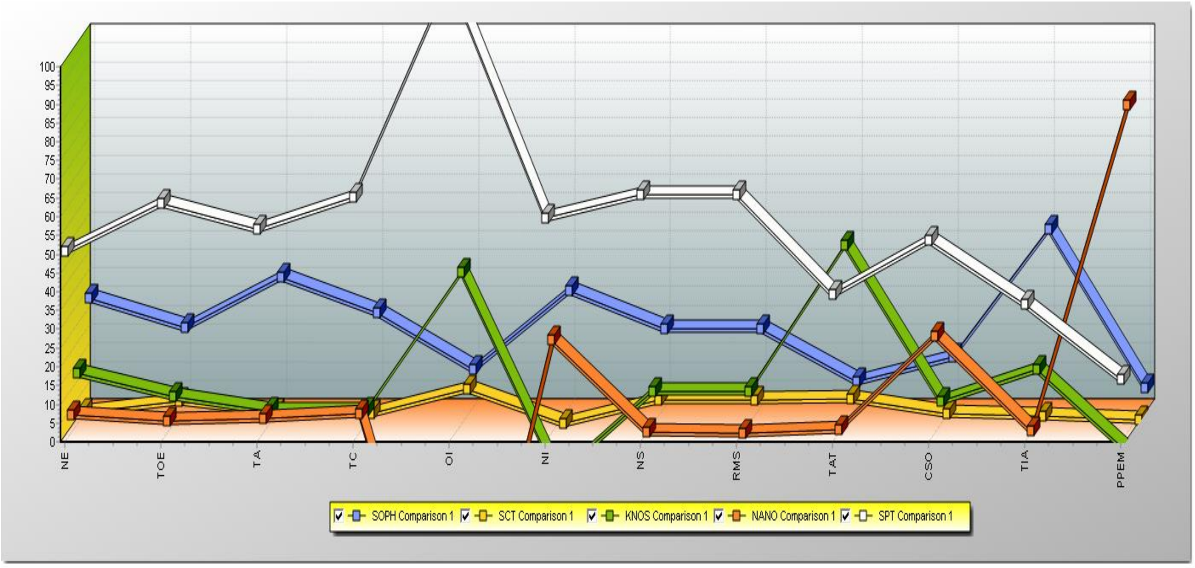


Figure 5.2 represents the reference set frequency in the technological industries with a sample of sixteen organizations. The global leader that most frequently appears in the reference set and considered the overall best performers are KNOS and SCT, followed by SGE. These organizations recur 5, 5, and 4 times respectively as part of the peer group over the total study analysis. Consequently, according to all types of efficiencies, the performance of these organizations is better compared to the other efficient organizations in the sample.

Figure 5.3: IMG reference contribution



As there are multiple peers for each inefficient organization, the analysis of "*reference contributions*" provides further guidance on selecting a peer from the reference set of an inefficient unit for benchmarking purposes. Reference contributions are also known as peer weights or lambda, in DEA mathematics. Figure 5.3 shows the reference set for the IMG organization, which consists of five other efficient organizations, namely KNOS, NANO, SCT, SOPH, and SPT. Figures 5.4 and 5.5 shows the reference set for the LRD and SDL organizations, namely FDM, KNOS, SCT, CCC, and SGE.

Figure 5.4: LRD reference contribution

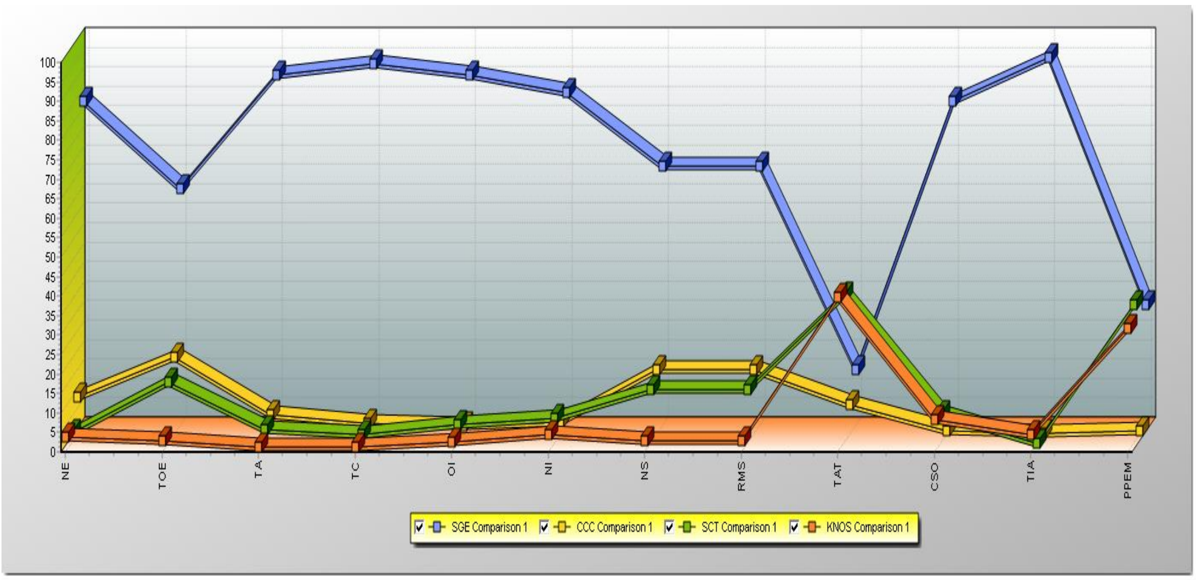
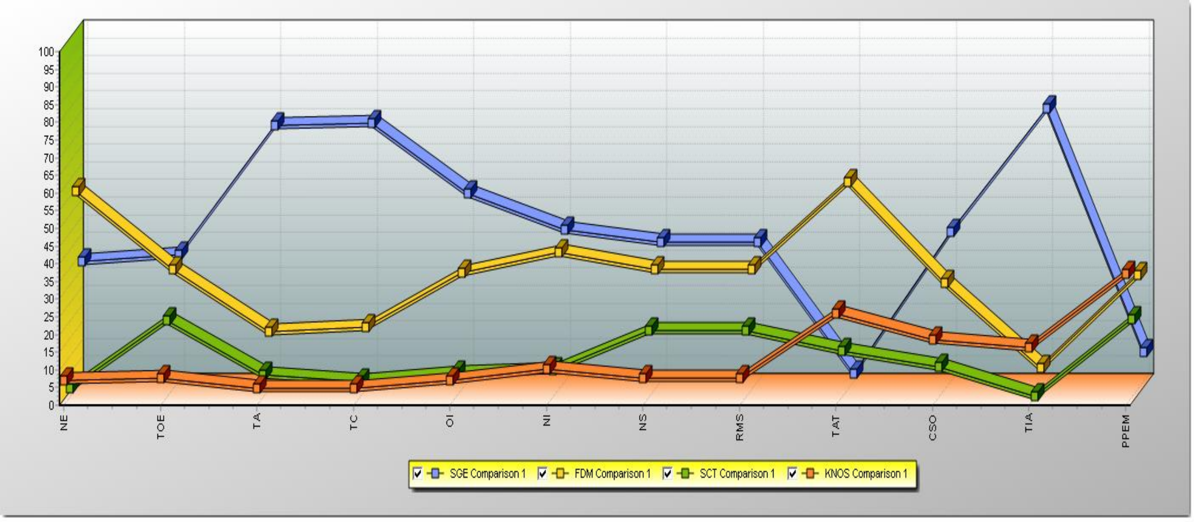


Figure 5.5: SDL reference contribution



5.2.2 Malmquist Productivity Index Results

This section determines the efficiency scores of the sixteen technological organizations in five different years (2016, 2015, 2014, 2013 and 2012), in terms of their ability to maximize their outputs using the same level of inputs by applying the combined DEA-BCC model. Hence, the results that are produced from this analysis show how the efficiency scores of the organizations changed during the period under consideration, and how different organizations operate relative to others.

Table 5.5: Efficiency scores in the technology industry from 2012 to 2016

DMU	Efficiency Scores					Average
	2016	2015	2014	2013	2012	
AVV	92%	95%	95%	85%	92%	92%
CCC	100%	100%	100%	100%	100%	100%
FDM	100%	100%	100%	100%	100%	100%
FDSA	100%	100%	100%	100%	100%	100%
IMG	78%	87%	81%	89%	93%	86%
KNOS	100%	100%	100%	100%	100%	100%
LRD	86%	88%	84%	85%	85%	86%
MCRO	100%	100%	100%	100%	100%	100%
NANO	100%	100%	100%	100%	100%	100%
NCC	100%	100%	100%	100%	100%	100%
SCT	100%	100%	100%	100%	100%	100%
SDL	88%	87%	84%	83%	87%	86%
SERV	100%	100%	100%	100%	100%	100%
SGE	100%	100%	100%	100%	100%	100%
SOPH	100%	100%	100%	100%	100%	100%
SPT	100%	100%	100%	100%	100%	100%
No. of efficient DMUs	12	12	12	12	12	12

Table 5.5 shows that there is no difference between scores across the entire period, which reflects that the technology industry obtains a stable efficiency score or consistent performance within the period from 2012 to 2016. Even the inefficient organizations maintain the same level of inefficiency within the examined period. Additionally, the average efficiency score for each organization showed the same status of efficiency scores for the year 2016.

The average efficiency score indicates that twelve out of sixteen organizations are efficient, with an efficiency score of 100%. Furthermore, it shows that three organizations are operating below the average, and all of them obtain an efficiency score of 86%, while the only organization that operates above average is AVV, with an efficiency score of 92%.

5.3 Oil and Gas Industry

The Oil and Gas industry includes seventeen organizations from two sectors: Oil and Gas Producers and Oil Equipment and Services. The list of organizations' names, codes, and sectors which are adopted in the analysis of the Oil & Gas industry are included the Appendix A, Table A.2.

5.3.1 BCC Model – Technical Efficiency

In order to evaluate the pure technical efficiency of the Oil & Gas industry, the BCC model will be applied and variable returns to scale will be examined.

5.3.1.1 Model Validation

As discussed in the previous section, the analysis will start with the model validation in order to check the validity of the applied BCC model. Each model will be operated with the target variables substituted in place of the actual variables. Table 5.6 represents the results of the BCC validation model. In each of the seventeen model runs, the substituted variables return an efficiency score of 100%, as expected. These results validate both the model and target variables.

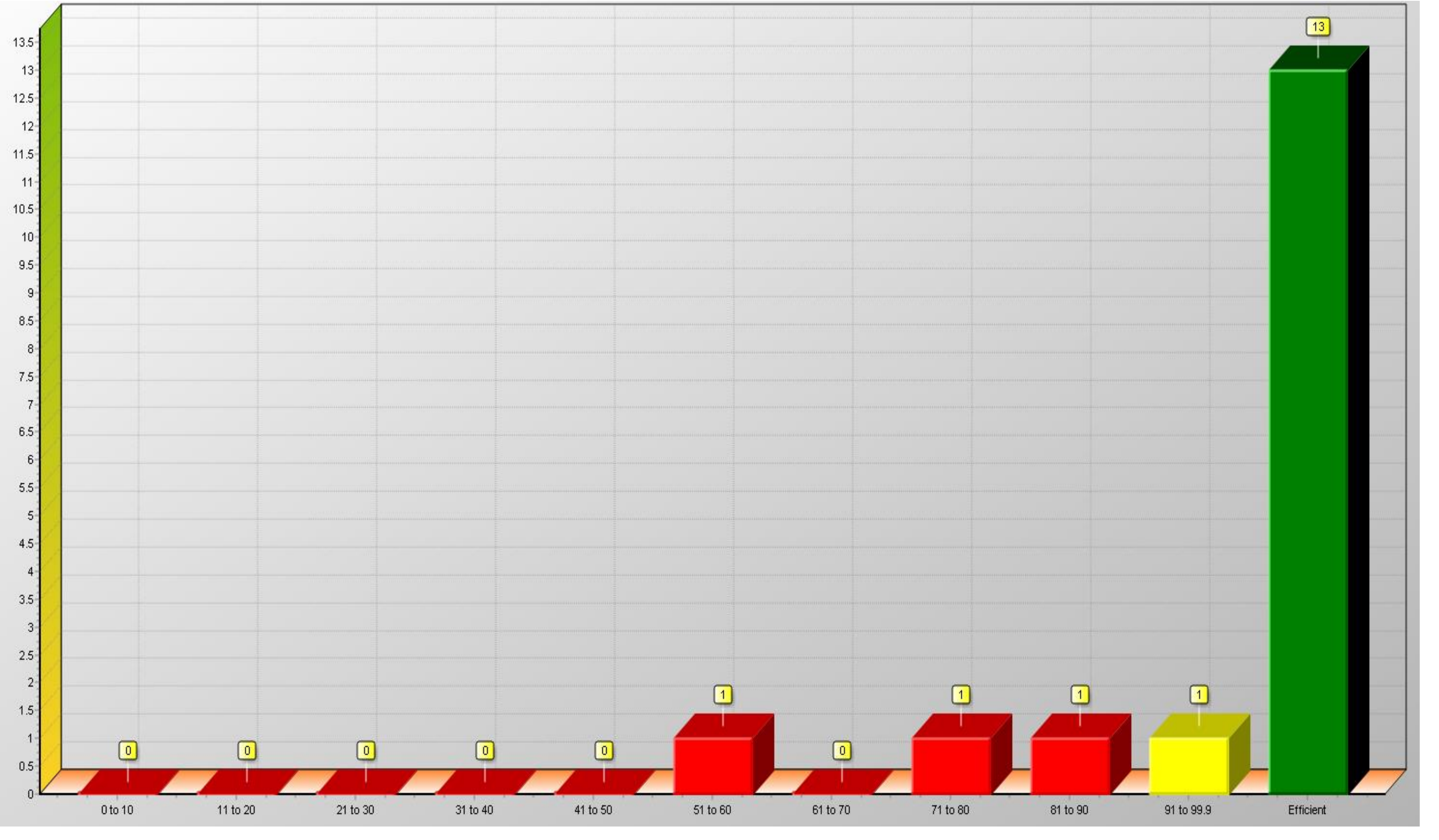
5.3.1.2 Efficiency scores

Based on the BCC model in Table 5.6, Figure 5.6 illustrates the technical efficiency scores and rankings for the seventeen organizations of the Oil and Gas industry. The graph shows that thirteen of the seventeen organizations are efficient and obtain 100% efficiency scores. These organizations are AMFW, CIU, CNE, EXI, LAM, RDSA, WG, BP., ENQ, OPHR, PFC, PMO GMS and. The efficiency scores provided are relative and not absolute.

Table 5.6: BCC Model Validation Results for Oil & Gas industry in 2016

No.	DMU	BCC model actual Result %	Target NE	Target TOE	Target TA	Target TC	Target OI	Target NI	Target NS	Target RMS	Target TAT	Target CSO	Target TIA	Target PPEM	BCC model validation Result %
1	AMFW	100	30900	5795000	5188000	2342000	-355000	-518000	5440000	0	1.05	389974	2675000	-16.76	100
2	CIU	100	16102	819000	666800	312400	44500	-41100	863500	0	1.29	121022	150300	-2.55	100
3	CNE	100	156	91412	1993438	1776009	-91412	-70660	1011554	0	0.12	577236	478652	-452.95	100
4	EXI	100	468	55841	444299	374978	38600	30132	94441	0	0.21	161511	194355	64.38	100
5	LAM	100	5189	518415	680500	482189	5953	-135511	524367	0	0.77	341655	202135	-26.12	100
6	RDSA	100	89000	207770318	376213800	257384844	3867799	4145042	211638118	0.08	0.56	8145342	22720716	46.57	100
7	WG.	100	25531	2907921	3193880	2192295	156940	20677	3064861	0	0.96	381025	1536440	0.81	100
8	BP.	100	74500	133966992	209704325	120440799	2152528	84792	136119520	0.05	0.65	19435077	23824747	1.14	100
9	ENQ	100	477	577991	3016309	2211326	53953	137759	631944	0	0.21	1159399	194355	288.8	100
10	GMS	100	2107	79023	764214	685983	54420	21948	133443	0	0.17	349528	194355	32.18	100
11	OPHR	100	288	174563	1790853	1431936	-94845	-57604	79718	0	0.04	706101	22720716	-200.01	100
12	PFC	100	13852	5489170	6632358	2337302	366688	744	5855859	0	0.88	339980	136248	0.05	100
13	PMO	100	801	461968	3857278	2870616	269475	91189	731443	0	0.19	510824	1015534	113.84	100
14	SIA	92.92	2107	109635	795361.5	694622	51239.15	18106.68	160874.1	0	0.2	357266.8	194708.2	37.72	100
15	TLW	87.1	888	1314946	4116750	2835382	55704.73	123956.8	1370651	0	0.2	1232868	1886298	253.38	100
16	HTG	80.92	2107	388442.9	1049515	781002.9	30510.18	-11095.6	418952.7	0	0.4	351714.2	381344.2	59.06	100
17	NOG	58.84	958	241347	1443367	1134126	29703.97	20214.62	439851.2	0	0.26	471763.9	290004.4	16.09	100

Figure 5.6: Distribution of efficiency scores for Oil & Gas industry in 2016



The BCC model measures only managerial efficiency. It shows that from this perspective the performance of the majority of the Oil and Gas organizations are efficient. As shown in Table 5.7, about 76% of the organizations analysed are technically efficient. This reflects that the managerial teams have a significant role and a positive impact on the overall efficiency of their organizations. The implication of this is that there are greater efficiencies to be achieved in other areas: i.e. scale efficiencies.

Table 5.7: Efficiency score category for Oil & Gas industry at 2016

Efficiency score categories	**Number**	**Percentage**
Efficient (Equal to 100%)	13	76 %
Above average (Less than 100% and ≤ 90%)	1	6%
Below average (Less than 90%)	3	18%
Total	17	100%

Additionally, as shown in Table 5.6, three organizations are performing below the average, with scores of 87.1%, 80.92%, and 58.84%: these are TLW, HTG, and NOG respectively. The only organization that is categorized as performing above the average is SIA, with an efficiency score of 92.92%.

<u>5.3.1.3 Return to scale</u>

Table 5.8 shows technical efficiency, decomposed into pure technical efficiency and scale efficiency. Technical efficiency scores are obtained from a CRS run, whereas pure technical efficiency scores are generated through a VRS run. The last column identifies the returns to scale prevailing in each DMU at the time of measurement.

Table 5.8: Returns to Scale for Oil & Gas industry in 2016

NO	DMU	Technical Efficiency %	Pure Technical Efficiency %	Scale Efficiency %	Returns to Scale
1	AMFW	100	100	100	Constant
2	BP.	100	100	100	Constant
3	CIU	100	100	100	Constant
4	CNE	100	100	100	Constant
5	ENQ	100	100	100	Constant
6	EXI	100	100	100	Constant
7	GMS	100	100	100	Constant
8	HTG	69.98	80.92	86.48%	Increasing returns
9	LAM	100	100	100	Constant
10	NOG	41.55	58.84	70.62%	Increasing returns

11	OPHR	100	100	100	Constant
12	PFC	100	100	100	Constant
13	PMO	100	100	100	Constant
14	RDSA	100	100	100	Constant
15	SIA	92.45	92.92	99.49%	Decreasing returns
16	TLW	44.9	87.1	51.55%	Increasing returns
17	WG.	100	100	100	Constant

It can be clearly seen that there is a high degree of similarity between the efficiency scores of the overall efficiency and pure technical efficiency. Thirteen of the seventeen organizations obtain 100% efficiency scores in both technical efficiency and scale efficiency, which reflects that these organizations have no “scale effects” in the assessment of their efficiency scores and that they are operating optimally for their size.

On the other hand, there are three common inefficient organizations operating below the average in either the BCC model or the CCR model, namely TLW, HTG, and NOG. All of these organizations are facing increasing returns to scale, which means that those organizations should consider expanding the scale of their operations in order to benefit from higher productivity. The only organization (SIA) that is operating above the average is obtaining decreasing returns to scale: in order to obtain a 100% efficiency score, it should consider downsizing.

5.3.1.4 Potential improvements

Once the inefficient organizations have been determined, in order to assist managers to determine aspects of deficiency and take decisions to deal with this situation, DEA provides the potential improvements that the inefficient organizations can follow to become efficient. Since the most efficient organizations have operated in the same environment, inefficient organizations could enhance their performance by choosing the same policies and managerial structures as their respective peer (reference) organizations. For efficient organizations, there are no changes to the actual values of their variables. Table 5.9 showed the potential improvements for each inefficient organization. Additionally, the table represents the reference set for each unit.

Table 5.9: Potential improvements in Oil & Gas industry in 2016

Category	**Variable**	**SIA (Efficiency: 92.92%)**	**TLW (Efficiency: 87.1%)**	**HTG (Efficiency: 80.92%)**	**NOG (Efficiency: 58.84%)**
Input	NE	0%	0%	0%	0%
	TOE	0%	0%	0%	0%
	TA	0%	0%	0%	0%
	TC	0%	0%	0%	0%
Financial	OI	-157%	176%	256%	170%
	NI	-133%	128%	186%	133%
Customer	NS	40%	36%	24%	70%
	RMS	40%	36%	24%	70%
Internal process	TAT	61%	62%	24%	70%
	CSO	101%	102%	105%	101%
Learning and growth	TIA	110%	118%	131%	130%
	PPEM	-105%	115%	124%	125%
	Reference set	ENQ EXI GMS LAM	BP. OPHR ENQ	RDSA OPHR ENQ EXI LAM	CNE PMO ENQ EXI LAM

As in the technology industry, it can be clearly seen that both the financial perspective (operating income, net income) and the learning and growth perspective (profit per employee, total intangible assets) are playing a dominant role in the potential improvements provided by the DEA, followed by the internal process perspective (common outstanding shares). The customer perspective has the least impact. For example, for the most inefficient organization (NOG), which obtains a 58.84% efficiency score, DEA indicates a potential increase in operating income by 170% and net income by 133%, followed by an increase in both intangible assets and profit per employees by 130%% and 125% respectively. These results are consistent with the nature of the return to scales, as they show that the organization should consider expanding the scale of its operations. Exactly the same conditions are shown for TLW and HTG, which have efficiency scores of 87.1% and 80.92%, respectively.

For organization SIA, which is considered to be performing above average, with an efficiency score of 92.92%, the potential improvements that have been suggested show that the financial, learning and growth, and internal process perspective variables are the most important. However, as the organization is obtaining decreasing returns to scale, this could justify the negative sign of the values of potential improvements in net income, operating income, and profit per employee, as the organization should consider downsizing.

5.3.1.5 Reference (Peer) Groups

Figure 5.7 represents the reference set frequency in the Oil and Gas industry with a sample of seventeen organizations, the global leader that most frequently appears in the reference set and the overall best performer, namely ENQ, followed by LAM and EXI. These organizations recur 5 and 4 times respectively as part of the peer group over the total study analysis. Consequently, according to all types of efficiencies, the performance of this organization is better compared to the other efficient organizations in the sample.

Figure 5.7: Reference Set Frequency for Oil and Gas industry in 2016

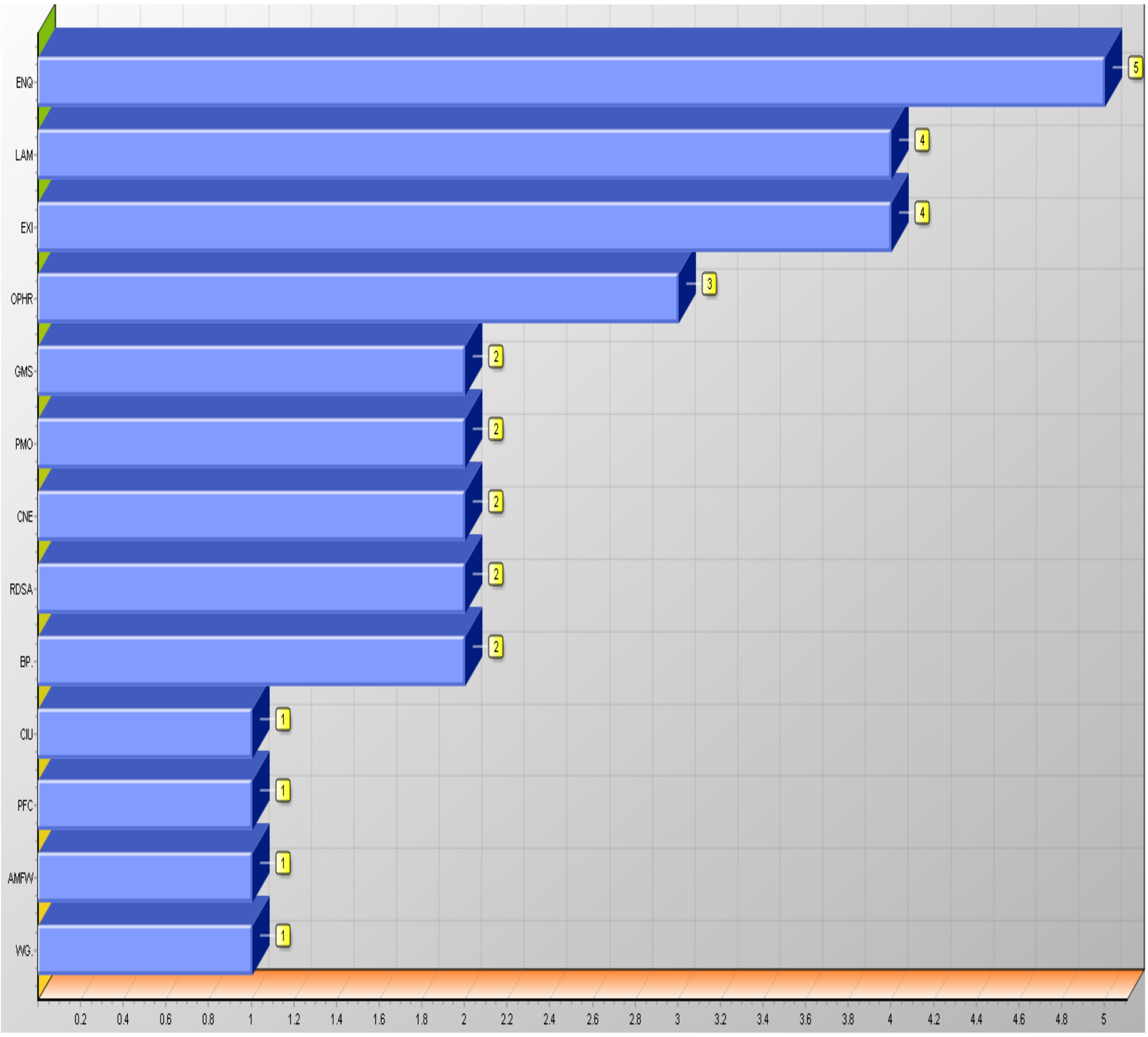
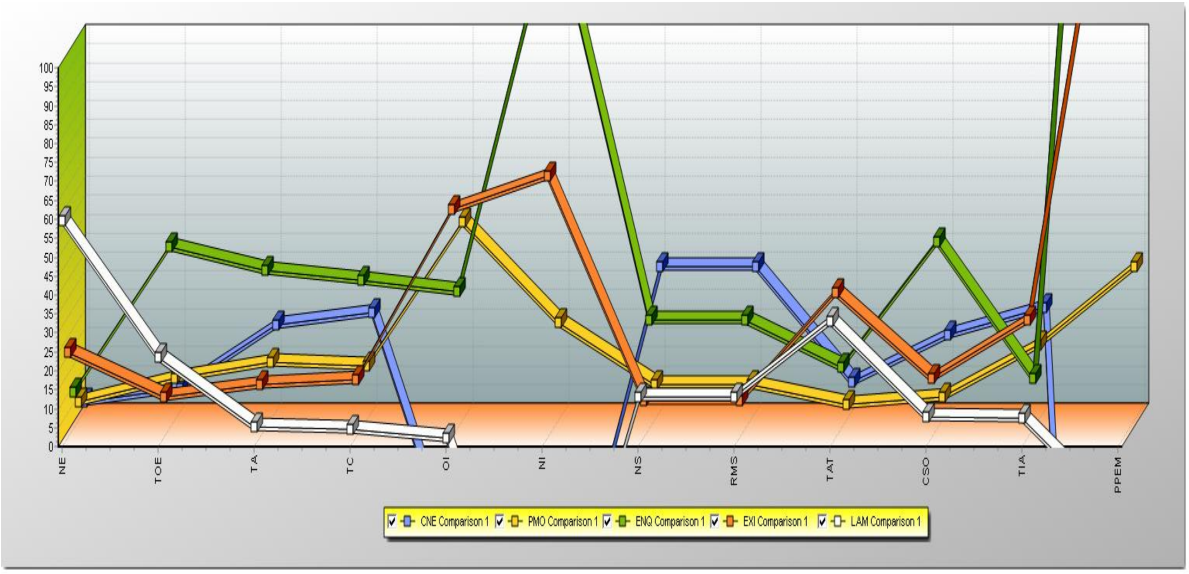


Figure 5.8: NOG reference contribution



As there are multiple peers for each inefficient organization, the analysis of "*reference contributions"* provides further guidance on selecting a peer from the reference set of an inefficient unit for benchmarking purposes. Figure 5.8 shows the reference set for the NOG organization, which consists of five other efficient organizations, namely CNE, PMO, ENQ, EXI, and LAM. Figures 5.9, 5.10, and 5.11 show the reference sets for organizations HTG, TLW, and SIA.

Figure 5.9: HTG reference contribution

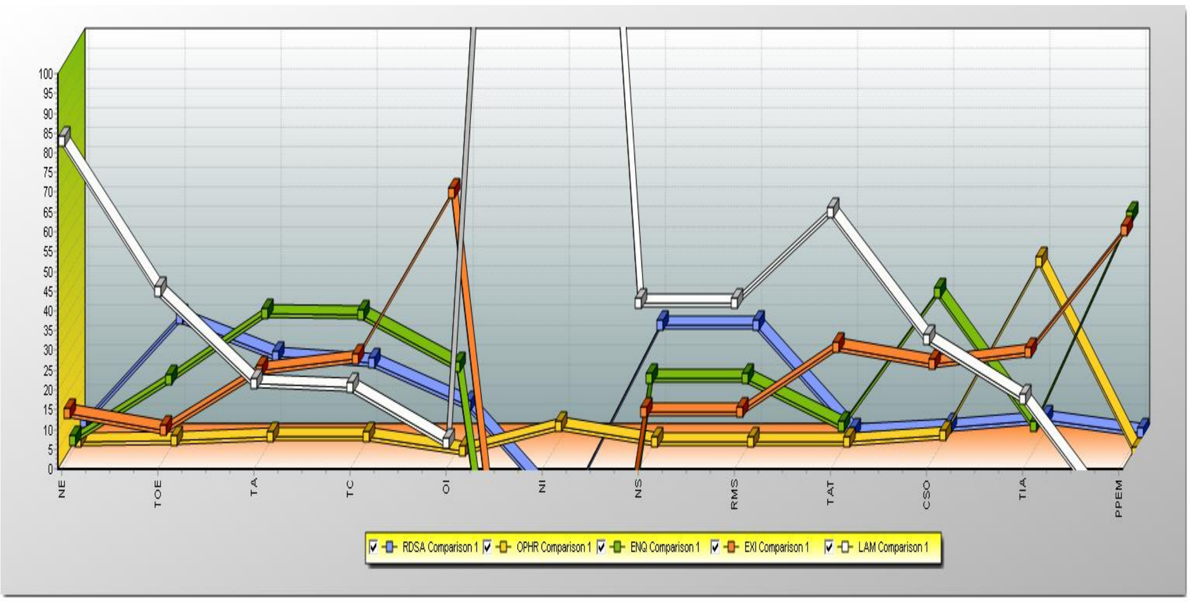


Figure 5.10: TLW reference contribution

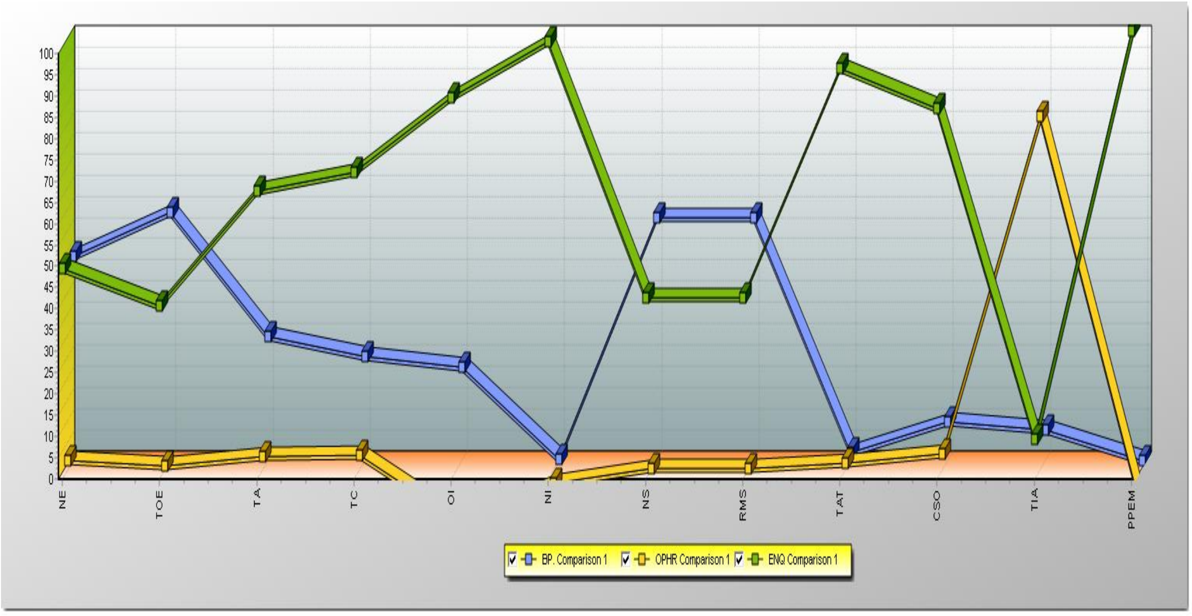
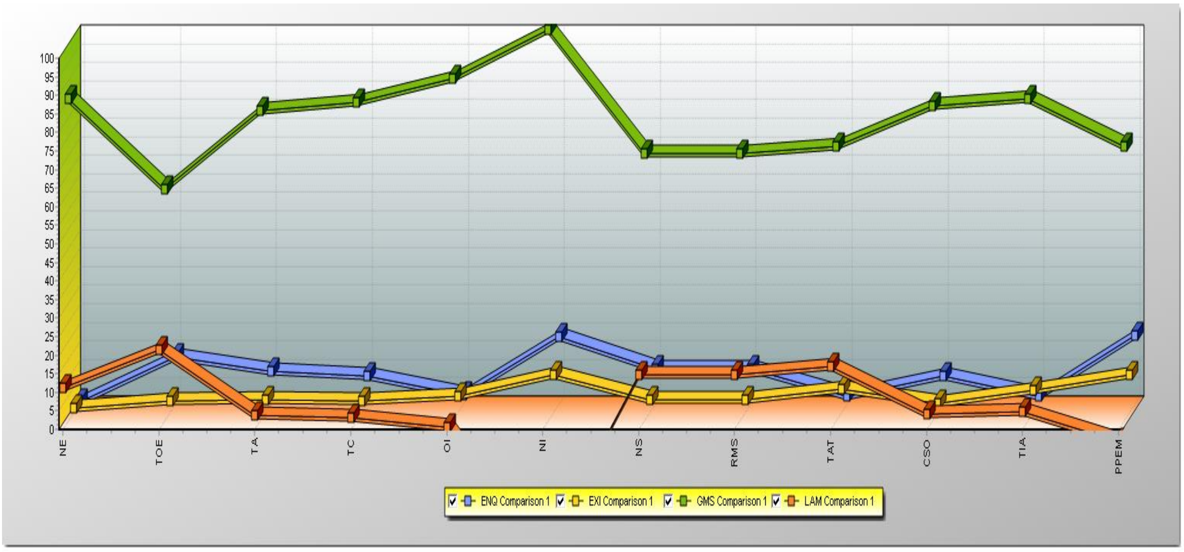


Figure 5.11: SIA reference contribution



5.3.2 Malmquist Productivity Index Results

This section determines the efficiency scores of seventeen Oil and Gas industry organizations in five different years (2016, 2015, 2014, 2013 and 2012) in terms of their ability to maximize their outputs using the same level of inputs by applying the combined DEA-BCC model. The results produced from this analysis show how the organizations' efficiency scores changed during the period under consideration, and how different organizations operate relative to others.

Table 5.10: Efficiency scores in Oil & Gas industry from 2012 to 2016

DMU	Efficiency Scores					Average
	2016	2015	2014	2013	2012	
AMFW	100%	100%	100%	100%	100%	100%
BP.	100%	100%	100%	100%	100%	100%
CIU	100%	100%	100%	100%	100%	100%
CNE	100%	100%	100%	100%	100%	100%
ENQ	100%	100%	100%	100%	100%	100%
EXI	100%	100%	100%	100%	100%	100%
GMS	100%	100%	100%	100%	100%	100%
HTG	81%	81%	100%	100%	100%	92%
LAM	100%	100%	100%	100%	100%	100%
NOG	59%	85%	100%	100%	100%	89%
OPHR	100%	100%	100%	100%	100%	100%
PFC	100%	100%	100%	100%	100%	100%
PMO	100%	100%	100%	100%	100%	100%
RDSA	100%	100%	100%	100%	100%	100%
SIA	93%	93%	100%	100%	100%	96%
TLW	87%	87%	100%	100%	100%	95%
WG.	100%	100%	100%	100%	100%	100%
No. of efficient DMUs	13	13	17	17	17	13

Overall, Table 5.10 shows that the Oil and Gas industry is considered as a stable industry. On average, thirteen out of seventeen organizations are efficient and the remaining four organizations are operating above average. For more details and an overview of the efficiency scores for each separate year, it can be found that with the exception of four organizations (NOG, HTG, TLW, and SIA), there is no difference between scores during the whole of the study period. This indicates that the majority of organizations in the Oil and Gas industry obtain stable efficiency scores or consistent performance within the period from 2012 to 2016. Furthermore, within the years 2012, 2013, and 2014, all the organizations of the industry were operating efficiently, with efficiency scores of 100%.

While the efficiency scores for NOG, HTG, TLW, and SIA decline from 2015, they were achieving efficiency scores of 100% in 2012, 2013, and 2014. For instance, NOG efficiency scores fell from 100% to 85% in 2015 and then reached 58% in 2016. HTG and TLW maintain the same below-average efficiency scores of 80.90% and 87.10% respectively.

5.4 Health Care Industry

The health care industry includes nineteen organizations in two sectors: Health Care Equipment and Services, and Pharmaceuticals and Biotechnology. The list of organizations' names, codes, and sectors which are adopted in the analysis of the health care industry are included in Appendix A, Table A.3.

5.4.1 BCC Model – Technical Efficiency

In order to evaluate the pure technical efficiency of the health care industry, the BCC model will be applied and variable returns to scale will be examined.

5.4.1.1 Model Validation

As discussed in the previous section, the analysis will start with the model validation in order to check the validity of the applied BCC model. Each model is operated with the target variables substituted in place of the actual variables. Table 5.11 presents the results of the BCC validation model. In each of the nineteen model runs, the substituted variables return an efficiency score of 100% as expected. These results validate both the model and target variables.

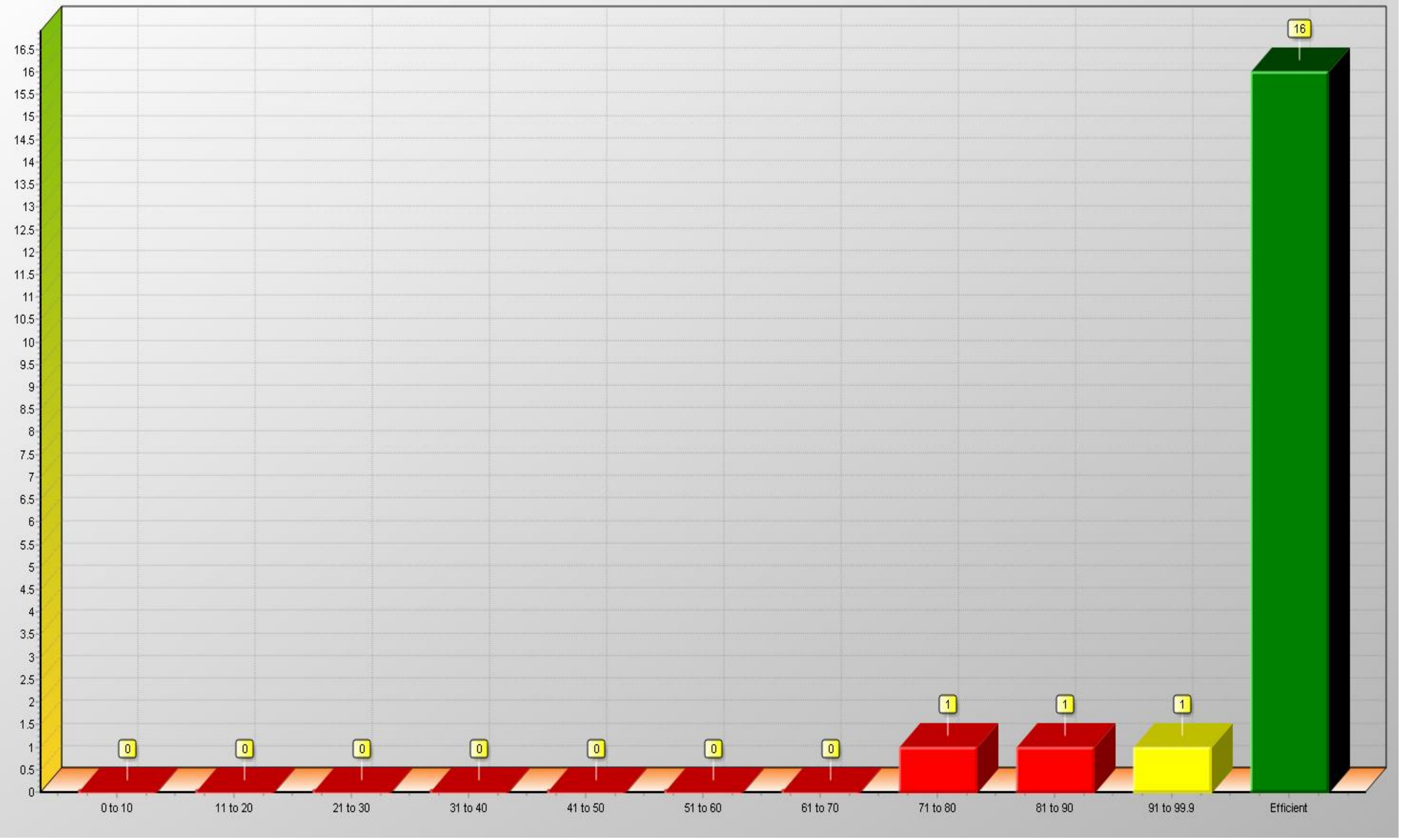
5.4.1.2 Efficiency scores

Based on the BCC model in Table 5.11, Figure 5.12 presents the technical efficiency scores and rankings for the nineteen organizations from the health care industry. The graph shows that sixteen out of nineteen organizations are efficient and obtain 100% efficiency score. These organizations are CMBN, BTG, CIR, CSRT, DPH, INDV, MGP, SHP, SN, UDG, VEC, AZN, CTEC, GHG, GSK, and OXB. The efficiency scores provided are relative and not absolute.

Table 5.11: BCC Model Validation Results for Health Care industry in 2016

No.	**DMU**	**BCC model actual Result %**	Target NE	Target TOE	Target TA	Target TC	Target OI	Target NI	Target NS	Target RMS	Target TAT	Target CSO	Target TIA	Target PPEM	**BCC model validation Result %**
1	AZN	100	59700	14059119	49814864	25278870	3049539	2602521	17108658	0.06	0.34	1265229	31826884	43.59	100
2	BTG	100	1182	393900	1142000	847700	53600	60500	447500	0	0.39	382992	787100	51.18	100
3	CIR	100	291	94100	317500	280700	-71000	-137300	447500	0	0.39	382992	176800	-471.82	100
4	CMBN	100	4417	182152	462776	371584	-97	123826	182055	0	0.39	184199	121711	28.03	100
5	CSRT	100	1984	252380	445760	209151	24530	14969	276910	0	0.62	49131	189938	7.54	100
6	CTEC	100	8524	1132867	2831931	2419456	122874	-150841	1255741	0	0.44	1951473	1980786	-17.7	100
7	DPH	100	1308	214854	560554	430705	32708	12668	247562	0	0.44	92747	360381	9.69	100
8	GHG	100	12811	115621	278338	233596	17404	15760	133025	0	0.48	127954	21461	1.23	100
9	GSK	100	99827	20479000	54707000	19624000	7410000	912000	27889000	0.1	0.51	4910110	24741000	9.14	100
10	INDV	100	934	499083	892100	112729	287847	26033	786930	0	0.88	720598	67313	27.87	100
11	MGP	100	8055	828500	1724400	1531000	97900	53600	926400	0	0.54	401081	25350	47.39	100
12	OXB	100	247	42013	56942	47004	-14237	-16641	27776	0	0.49	3088047	1330	-67.37	100
13	SHP	100	23906	7018402	54287286	39615566	1458275	448877	8476677	0.03	0.16	912200	42647003	18.78	100
14	SN.	100	15584	2810782	5877317	4478342	661973	583131	3472756	0.01	0.59	875923	2918789	37.42	100
15	UDG	100	7499	853967	1250912	939876	89113	193272	943080	0	0.75	246764	441575	25.77	100
16	VEC	100	453	213199	845900	681500	-44954	-42693	168245	0	0.2	677969	619600	-94.25	100
17	HIK	91.84	3799	1138742	3177271	1276947	429241.2	125530.4	1579261	0.01	0.84	758465.1	1517978	15.05	100
18	GNS	82.24	2460	348900	734400	309364.9	123960.2	59945.27	472860.2	0	0.64	372828.7	199412.3	23.97	100
19	SPI	80.39	3350	828500	1724400	902401.5	309405.3	74231.3	1152341	0	0.79	829337.2	644087.1	8.28	100

Figure 5.12: Distribution of efficiency scores for Health Care industry at 2016



The BCC model measures only managerial efficiency. From this perspective, the performance of the majority of the health care organizations is efficient. As shown in Table 5.12, about 84% of the organizations analysed are technically efficient. This reflects that the managerial teams have a significant role and a positive impact on the overall efficiency of their organizations. The implication of this is that there are greater efficiencies to be achieved in other areas: i.e. scale efficiencies.

Table 5.12: Efficiency score category for health care industry in 2016

Efficiency score categories	Number	Percentage
Efficient (Equal to 100%)	16	84 %
Above average (Less than 100% and ≤ 90%)	1	5%
Below average (Less than 90%)	2	11%
Total	17	100%

Additionally, as shown in Table 5.11, two organizations are performing below the average, with scores of 82.24% and 80.39%, namely GNS and SPI respectively. The only organization that is categorized as performing above the average is HIK, with an efficiency score of 91.84%.

5.4.1.3 Return to scale

Table 5.13 shows technical efficiency, decomposed into pure technical efficiency and scale efficiency. Technical efficiency scores are obtained from a CRS run, whereas pure technical efficiency scores are generated through a VRS run. The last column identifies the returns to scale prevailing in each DMU at the time of measurement.

Table 5.13: Returns to Scale for health care industry in 2016

NO	DMU	Technical Efficiency %	Pure Technical Efficiency %	Scale Efficiency %	Returns to Scale
1	AZN	100	100	100	Constant
2	BTG	100	100	100	Constant
3	CIR	100	100	100	Constant
4	CMBN	100	100	100	Constant
5	CSRT	100	100	100	Constant
6	CTEC	100	100	100	Constant
7	DPH	100	100	100	Constant
8	GHG	100	100	100	Constant
9	GNS	81.13	82.24	98.65	Increasing returns
10	GSK	100	100	100	Constant
11	HIK	88.31	91.84	96.16	Decreasing returns

12	INDV	100	100	100	Constant
13	MGP	76.35	100	76.35	Increasing returns
14	OXB	100	100	100	Constant
15	SHP	100	100	100	Constant
16	SN.	100	100	100	Constant
17	SPI	79.85	80.39	99.33	Increasing returns
18	UDG	100	100	100	Constant
19	VEC	80.38	100	80.38	Increasing returns

The results from Table 5.13 show that the efficiency scores of the overall efficiency and pure technical efficiency for fourteen of the nineteen organizations are the same, at 100%, which demonstrates that they are operating efficiently and are at their optimal size, or in other words, that they have no scale effects. Furthermore, although MGP and VEC achieve 100% technical efficiency scores, they obtain scores of 76.35% and 80.38% in scale efficiency and both obtain an increasing return to scale, which means that these organizations should consider expanding the scale of their operations in order to benefit from higher productivity.

GNS and SPI both obtain an increasing return to scale. They are similar in that both are operating below the average in both the BCC model and the CCR model. The only organization operating above the average and obtaining decreasing returns to scale is HIK. Hence, in order to obtain a 100% efficiency score, it should consider downsizing.

5.4.1.4 Potential improvements

Once the inefficient organizations have been determined, in order to assist managers to determine aspects of deficiency and take decisions to deal with this situation, DEA provides the potential improvements that the inefficient organizations can follow to be efficient. Since the most efficient organizations have operated in the same environment, inefficient organizations could enhance their performance by choosing the same policies and managerial structures as their respective peer (reference) organizations.

For the efficient organizations there are no changes to the actual values of their variables. Table 5.14 shows the potential improvements for each inefficient organization. Additionally, the table represents the reference set for each unit.

Table 5.14: Potential improvements in health care industry at 2016

Category	Variable	HIK (Efficiency: 91.84%)	GNS (Efficiency: 82.24%)	SPI (Efficiency: 80.39%)
Input	NE	0%	0%	0%
	TOE	0%	0%	0%
	TA	0%	0%	0%
	TC	0%	0%	0%
Financial	OI	-138%	215%	216%
	NI	9%	22%	39%
Customer	NS	9%	22%	24%
	RMS	9%	22%	24%
Internal process	TAT	98%	22%	48%
	CSO	115%	211%	107%
Learning and growth	TIA	9%	22%	24%
	PPEM	9%	22%	24%
	Reference set	GSK AZN SHP INDV CIR	CMBN UDG CSRT SHP BTG INDV	SN. CTEC SHP INDV CIR

Table 5.14 shows that the health care industry is similar to both the technology and the oil and gas industry in that both the financial perspective (operating income) and the internal process perspective (common outstanding shares) play a significant role in achieving the target efficiency score and that the BSC perspectives which have the least impact are the customer perspective and the learning and growth perspective has a slight effect on efficiency scores.

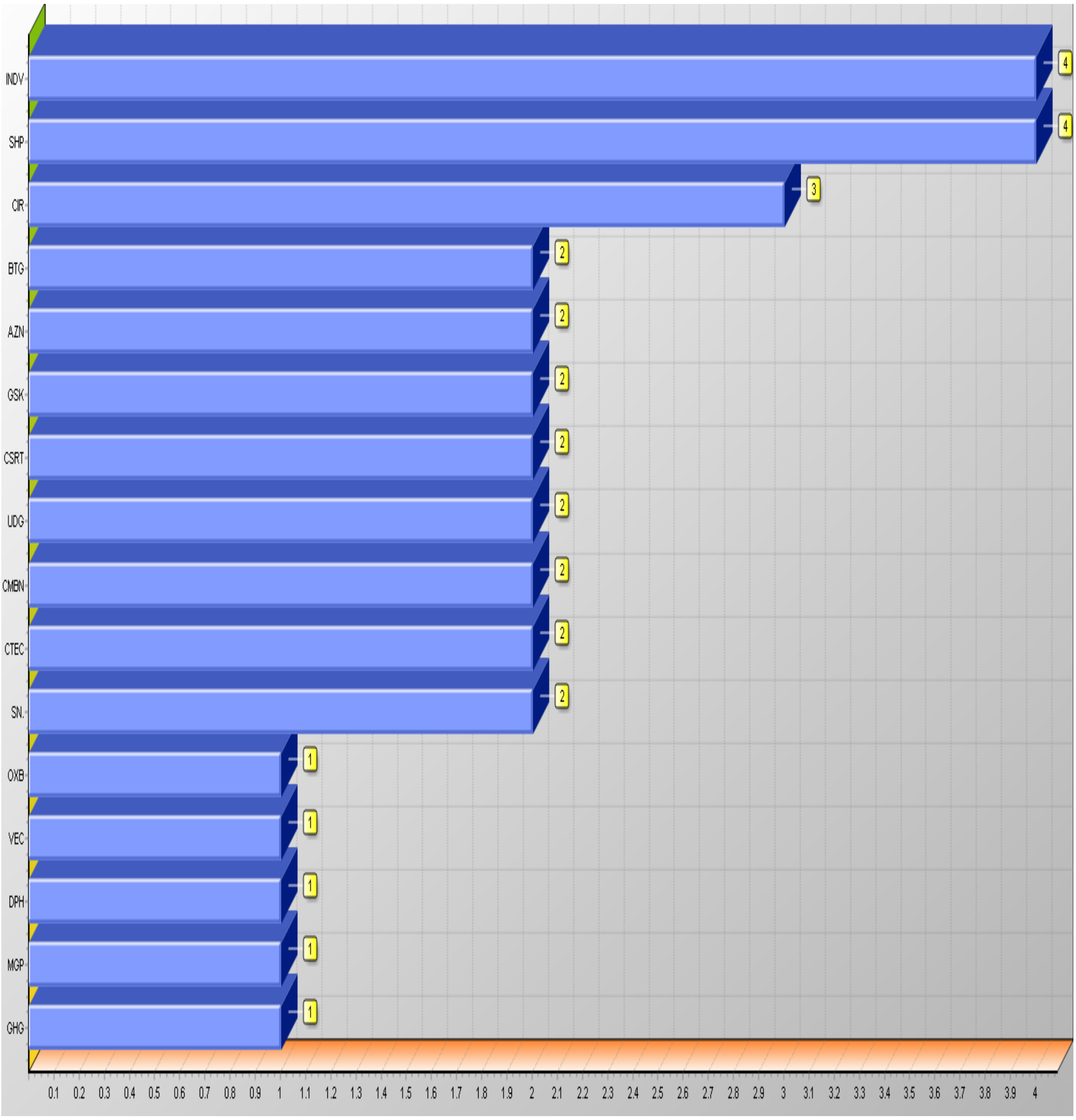
For instance, for the most inefficient organizations (SPI and GNS), which obtain efficiency scores of 80.39% and 82.24 respectively, DEA indicates a potential increase in operating income by 216% and 215%, respectively, followed by an increase in the number of outstanding shares by 107% and 211% respectively. These results are consistent with the nature of the return of scales, as they show that the organizations should consider expanding the scale of their operations.

HIK is considered to be performing above average, with an efficiency score of 91.84%, and obtaining decreasing returns to scale. Additionally, the potential improvements that have been suggested in order to achieve 100% efficiency scores are that the organization should decrease its operating income by 138% and increase the number of outstanding shares by 115%.

5.4.1.5 Reference (Peer) Groups

Figure 5.13 represents the reference set frequency in the health care industry with a sample of nineteen organizations, the global leader that most frequently appears in the reference set and the overall best performers, namely INVD and SHP, followed by CIR. These organizations recurred 4 and 3 times respectively as part of the peer group over the total study analysis. Consequently, according to all types of efficiencies, the performance of this organization is better compared to the other efficient organizations in the sample.

Figure 5.13: Reference Set Frequency for health care industry in 2016



As there are multiple peers for each inefficient organization, the analysis of "*reference contributions"* provides further guidance on selecting a peer from the reference set of an inefficient unit for benchmarking purposes. Figure 5.14 shows that the reference set for the SPI organization consists of five other efficient organizations, namely SN, CTEC, SHP, INDV, and CIR. Figures 5.15 and 5.16 show the reference sets for organizations GNS and HIK.

Figure 5.14: SPI reference contribution

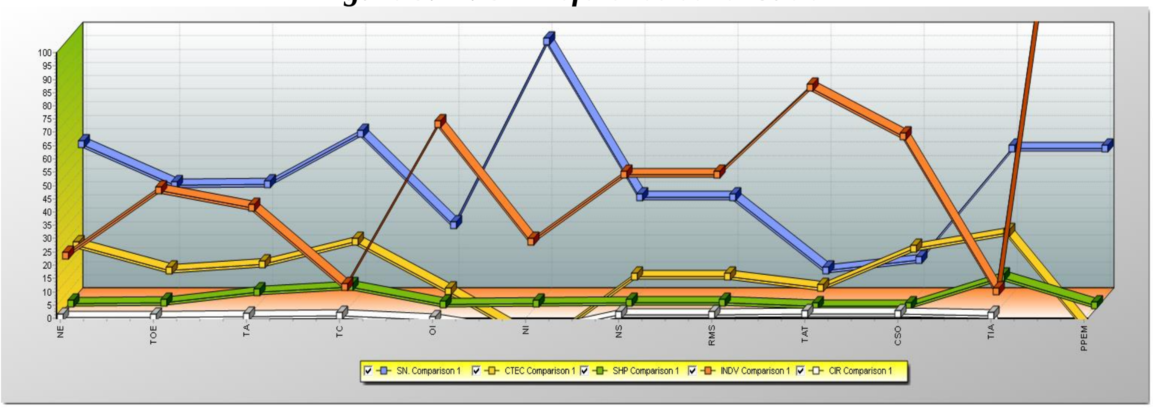


Figure 5.15: GNS reference contribution

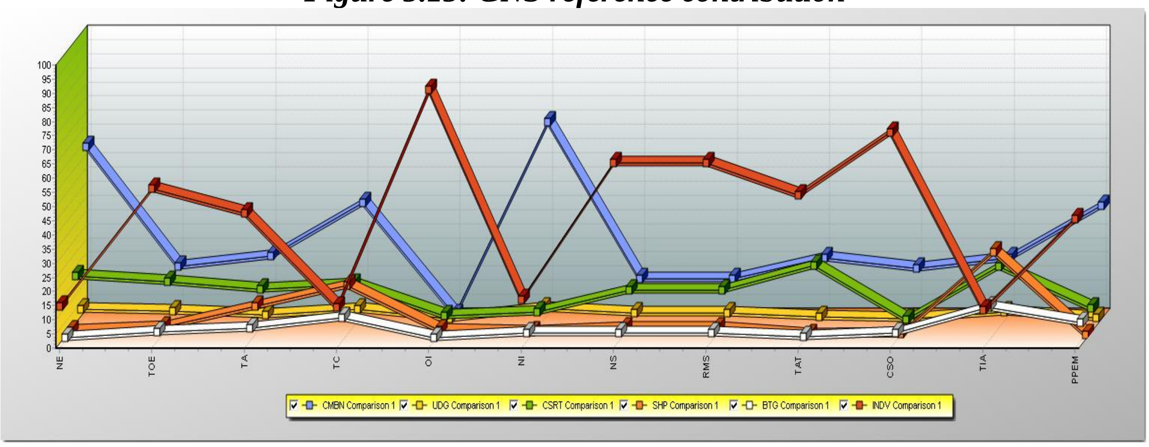
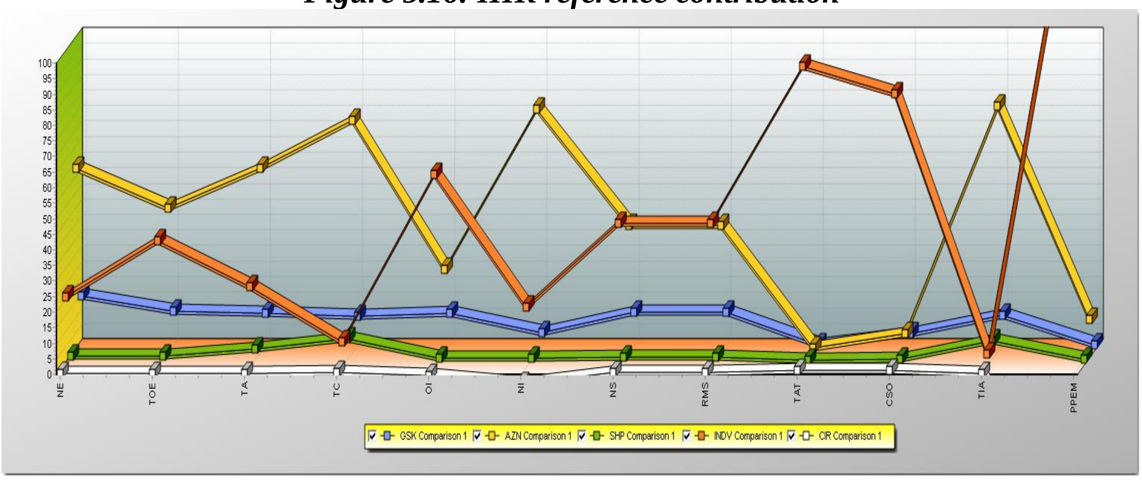


Figure 5.16: HIK reference contribution



5.4.2 Malmquist Productivity Index Results

This section determines the efficiency scores of nineteen health care industry organizations in five different years (2016, 2015, 2014, 2013 and 2012) in terms of their ability to maximize their outputs using the same level of inputs by applying the combined DEA-BCC model. Hence, the results that are produced from this analysis show how the efficiency scores of the organizations changed during the period under consideration, and how different organizations operate relatively to others.

Table 5.15: Efficiency scores in health care industry from 2012 to 2016

DMU	Efficiency Scores					Average
	2016	2015	2014	2013	2012	
AZN	100%	100%	100%	100%	100%	100%
BTG	100%	100%	100%	100%	100%	100%
CIR	100%	100%	100%	100%	100%	100%
CMBN	100%	85%	61%	56%	50%	70%
CSRT	100%	100%	100%	100%	100%	100%
CTEC	100%	100%	100%	100%	100%	100%
DPH	100%	100%	100%	100%	100%	100%
GHG	100%	100%	100%	100%	100%	100%
GNS	82%	67%	60%	53%	48%	62%
GSK	100%	100%	100%	100%	100%	100%
HIK	92%	89%	84%	75%	58%	79%
INDV	100%	100%	100%	100%	100%	100%
MGP	100%	78%	69%	63%	58%	74%
OXB	100%	100%	100%	100%	100%	100%
SHP	100%	100%	100%	100%	100%	100%
SN.	100%	100%	100%	100%	100%	100%
SPI	80%	78%	72%	70%	66%	73%
UDG	100%	100%	100%	100%	100%	100%
VEC	100%	100%	100%	100%	100%	100%
No. of efficient DMUs	14	14	14	14	14	14

Overall, fourteen of the nineteen organizations are considered stable in their status. Table 5.15 shows that each organization within the industry is fixed according to their efficiency condition, except for CMBN and MGP. In 2016, these two organizations shifted from inefficient to efficient, whereas in 2016, the efficiency score for HIK organization improved as it shifted from operating below the average to operating above the average. However, the efficiency scores for another two organizations (SPI and GNS) are inefficient during the whole examined period. For instance, SPI's efficiency scores ranged between 73% and 80%, while GNS's scores ranged between 62% and 82%.

5.5 Basic Materials Industry

The basic materials industry includes twenty-six organizations in four sectors: Mining, Chemicals, Forestry and Paper, Industrial Metals and Mining. The list of organizations' names, codes, and sectors which are adopted in the analysis of the basic materials industry is included in Appendix A, Table A.4.

5.5.1 BCC Model – Technical Efficiency

In order to evaluate the pure technical efficiency of the basic materials industry, the BCC model will be applied and variable returns to scale will be examined.

5.5.1.1 Model Validation

The analysis will start with the model validation in order to check the validity of the applied BCC model. Each model will be operated with the target variables substituted in place of the actual variables. Table 5.16 presents the results of the BCC validation model. In each of the 26 model runs, the substituted variables return an efficiency score of 100%, as expected. These results validate both the model and target variables.

5.5.1.2 Efficiency scores

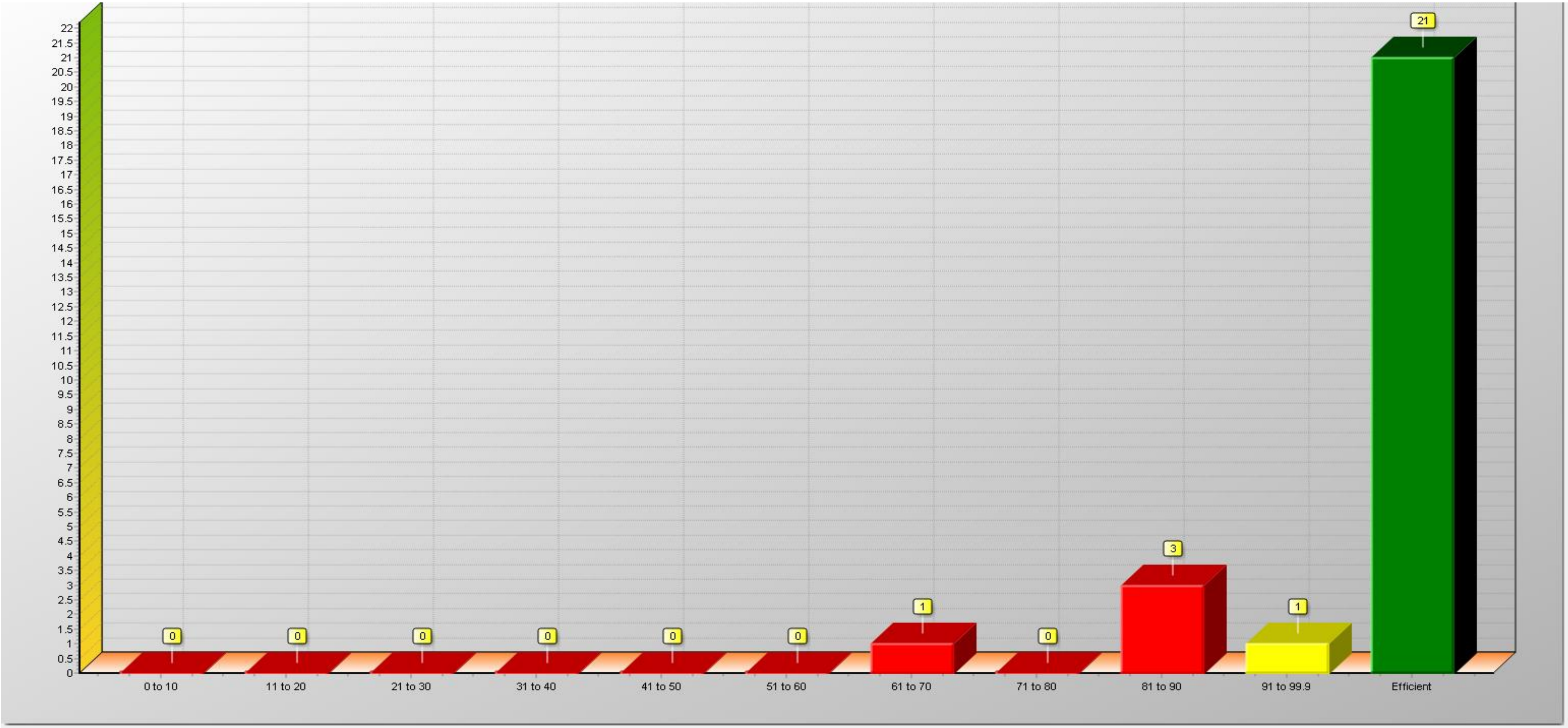
Based on the BCC model in Table 5.16, figure 5.17 presents the technical efficiency scores and rankings for the twenty-six organizations of the basic materials industry. The graph shows that twenty-one of the twenty-six organizations are efficient, obtaining 100% efficiency scores. These organizations are CAR, FXPO, SYNT, AAL, ANTO, BLT, CRDA, ELM, EVR, GEMD, GLEN, JMAT, KAZ, KMR, MNDI, POG, RIO, RRS, SXX, TET, and ZTF. The efficiency scores provided are relative and not absolute.

Table 5.16: BCC Model Validation Results for basic materials industry in 2016

No.	**DMU**	**BCC model actual Result %**	Target NE	Target TOE	Target TA	Target TC	Target OI	Target NI	Target NS	Target RMS	Target TAT	Target CSO	Target TIA	Target PPEM	**BCC model validation Result %**
1	CAR	100	1340	109114	116496	63613	9860	2200	118974	0	1.02	66213	20257	1.64	100
2	FXPO	100	9104	514087	900339	672261	219532	139352	733619	0	0.81	588624	28563	15.31	100
3	SYNT	100	2326	944500	1076200	546500	101200	110400	1045700	0	0.97	339881	355800	47.46	100
4	AAL	100	80000	13423178	39849296	28942968	2477564	1185601	15900743	0.01	0.4	1402243	2608987	14.82	100
5	ANTO	100	5427	2007192	11062851	8753204	686593	117519	2693784	0	0.24	985866	121731	21.65	100
6	BLT	100	26827	19125995	84717306	68971089	1919203	-4346972	21045199	0.02	0.25	5322443	3093369	-162.04	100
7	CRDA	100	4273	945400	1443500	1023500	298200	196700	1243600	0	0.86	131248	355300	46.03	100
8	ELM	100	1395	420464	729981	508659	70065	50652	490530	0	0.67	463496	291879	36.31	100
9	EVR	100	77951	5010913	7337928	5015224	725939	-159915	5736852	0	0.78	1419512	954547	-2.05	100
10	GEMD	100	446	103578	279592	165304	37605	-118121	141182	0	0.5	138361	11365	-264.85	100
11	GLEN	100	25535	112240142	99623240	54311859	1521051	1025686	113761193	0.09	1.14	1439741	5446676	40.17	100
12	JMAT	100	627	10275800	4035000	2670500	438100	333100	10713900	0.01	2.66	193533	795000	531.26	100
13	KAZ	100	12125	408341	4042835	3229402	161402	131651	569743	0	0.14	446692	6488	10.86	100
14	KMR	100	1344	148219	875235	830226	-20026	-13796	128194	0	0.15	109602	127984	-10.26	100
15	MNDI	100	25400	4659655	6231316	4119136	809447	523760	5469102	0	0.88	484217	685239	20.62	100
16	POG	100	8064	329748	1125640	872262	72407	25080	402155	0	0.36	3303769	39958	3.11	100
17	RIO	100	51029	20797112	69368885	50877274	4328858	3434078	25125970	0.02	0.36	1799012	3430530	67.3	100
18	RRS	100	2915	609752	3277217	3045080	283374	184069	893126	0	0.27	93804	21393	63.15	100
19	SXX	100	3105	11872	823492	496272	-11872	-22954	783607	0	0.39	4164514	150204	-353.14	100
20	TET	100	316	78491	69160	44942	9549	6149	88040	0	1.27	52655	3364	19.46	100
21	ZTF	100	339	49730	90768	61847	7646	5795	57376	0	0.63	44414	7547	17.09	100
22	ACA	91.51	2927	602801	1850339	1568389	206796.4	135562.5	856270.79	0	0.56	448112.1	191588.3	24.85	100
23	PDL	89.35	4403	325300	1021406	864000	132593.5	83387.22	482276.4	0	0.61	586670.4	23943.7	12.13	100

24	VED	87.86	23149	6631398	18154613	13094405	1321327	990039.4	8138141.85	0.01	0.65	1599172	1117899	-54.53	100
25	HOC	82.98	3964	425011	1082208	879469	151530.5	96044.47	615583.59	0	0.85	611288.5	87189.72	10.3	100
26	LMI	69.59	3956	767396	1525060	1138039	248493.1	161291	1137307.12	0	0.73	752485.2	290722.3	-14.17	100

Figure 5.17: Distribution of efficiency scores for basic materials industry in 2016



The BCC model measures only managerial efficiency. From this perspective, the performance of the majority of the basic materials organizations is efficient. As shown in Table 5.17, about 81% of organizations in the analysis are technically efficient. This reflects that the managerial teams have a significant role and a positive impact on the overall efficiency of their organizations. The implication of this is that there are greater efficiencies to be achieved in other areas: i.e. scale efficiencies.

Table 5.17: Efficiency score category for basic materials industry in 2016

Efficiency score categories	**Number**	**Percentage**
Efficient (Equal to 100%)	21	81 %
Above average (Less than 100% and ≤ 90%)	1	4%
Below average (Less than 90%)	4	15%
Total	26	100%

Additionally, as shown in Table 5.16, four organizations are performing below average, with scores of 89.35%, 87.86%, 82.98%, and 69.59%, namely PDL, VED, HOC, and LMI respectively. The only organization that is categorized as performing above the average is ACA, with an efficiency score of 91.51%.

5.5.1.3 Return to scale

Table 5.18 shows technical efficiency, decomposed into pure technical efficiency and scale efficiency. Technical efficiency scores are obtained from a CRS run, whereas pure technical efficiency scores are generated through a VRS run. The last column identifies the returns to scale prevailing in each DMU at the time of measurement.

Table 5.18: Returns to Scale for basic materials industry in 2016

NO	**DMU**	**Technical Efficiency %**	**Pure Technical Efficiency %**	**Scale Efficiency %**	**Returns to Scale**
1	AAL	73.7	100	73.70	Increasing returns
2	ACA	90.41	91.51	98.80	Increasing returns
3	ANTO	100	100	100	Constant
4	BLT	90.28	100	90.28	Increasing returns
5	CAR	97.65	100	97.65	Decreasing returns
6	CRDA	100	100	100	Constant
7	ELM	100	100	100.00	Constant
8	EVR	75.3	100	75.30%	Increasing returns
9	FXPO	100	100	100	Constant
10	GEMD	100	100	100	Constant
11	GLEN	93.5	100	93.50	Increasing returns

12	HOC	73.15	82.98	88.15	Increasing returns
13	JMAT	100	100	100	Constant
14	KAZ	100	100	100	Constant
15	KMR	100	100	100	Constant
16	LMI	56.8	69.59	81.62	Increasing returns
17	MNDI	84.38	100	84.38	Increasing returns
18	PDL	85.78	89.35	96.00	Increasing returns
19	POG	100	100	100	Constant
20	RIO	100	100	100	Constant
21	RRS	100	100	100	Constant
22	SXX	100	100	100	Constant
23	SYNT	100	100	100	Constant
24	TET	100	100	100	Constant
25	VED	72.42	87.86	82.43	Increasing returns
26	ZTF	100	100	100	Constant

The results in Table 5.18 show that the overall efficiency and pure technical efficiency scores for fifteen out of twenty-six organizations are the same, at 100%, which in turn proves that they are operating efficiently and at their optimal size (i.e. they have no scale effects).

Furthermore, the only organization obtaining decreasing returns to scale is CAR. Although this organization achieved 100% technical efficiency, its overall efficiency is 97.65% due to scale inefficiency. Hence, it should downsize its operations. Of the remaining ten organizations obtaining increasing returns to scale, five (AAL, BLT, EVR, GLEN, and MNDI) are similar in that they achieved 100% technical efficiency, which reflects that in order to achieve 100% overall efficiency, they should expand the scale of their operations in order to benefit from higher productivity, whereas the other five (ACA, HOC, LMI, PDL, and VED) are inefficient in both technical efficiency and scale efficiency.

5.5.1.4 Potential improvements

Once the inefficient organizations have been determined, in order to assist managers to determine aspects of deficiency and take decisions to deal with this situation, DEA provides the potential improvements that the inefficient organizations can follow to be efficient. Since the most efficient organizations are operating in the same environment, inefficient organizations could enhance their performances by choosing the same policies and managerial structures as their respective peer (reference) organizations. For efficient organizations, there are no changes to the actual values of their variables. Table 5.19 shows the potential improvements for each inefficient organization. Additionally, the table represents the reference set for each unit.

Table 5.19: Potential improvements in basic materials industry in 2016

Category	Variable	ACA (Efficiency: 91.51%)	PDL (Efficiency: 89.35%)	VED (Efficiency: 87.86%)	VED (Efficiency: 82.98%)	VED (Efficiency: 69.59%)
Input	NE	0%	0%	0%	0%	0%
	TOE	0%	0	0	0%	0%
	TA	0%	0%	0%	0%	0%
	TC	0%	0%	0%	0%	0%
Financial	OI	114%	126%	155%	177%	232%
	NI	192%	154%	181%	184%	167%
Customer	NS	9%	12%	14%	21%	15%
	RMS	9%	12%	14%	21%	19%
Internal process	TAT	95%	90%	83%	95%	94%
	CSO	9%	12%	17%	21%	17%
Learning and growth	TIA	9%	12%	13%	31%	15%
	PPEM	9%	12%	14%	21%	15%
	Reference set	CRDA ELM ZTF FXPO RRS SXX	ELM ZTF FXPO RRS SXX POG	CRDA MNDI RIO SXX	CRDA TET FXPO RRS SXX POG	CRDA TET RRS SXX

Table 5.18 shows that the basic materials industry is similar to the technology, oil and gas, and health care industries in that the financial perspective indicators (operating income and net income) are playing a significant role in achieving the target efficiency scores. This is followed by the internal process perspective variable of total assets turnover. The other perspectives of the BSC (the learning and growth and customer perspectives) have a smaller effect on the efficiency scores.

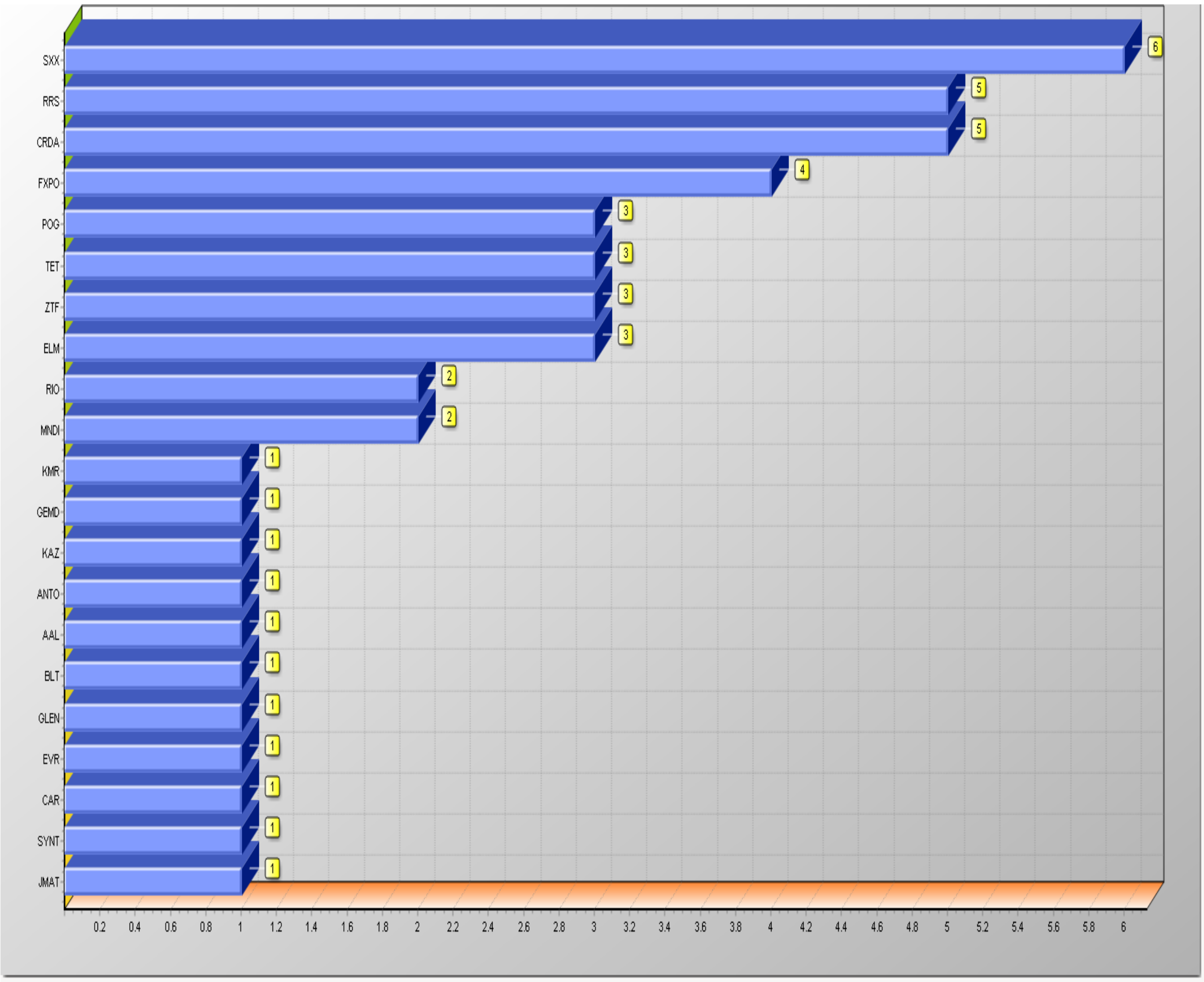
For instance, organization ACA is considered to be performing above the average, with an efficiency score of 91.51%, and obtaining increasing returns to scale. The results reveal that in order to achieve 100% efficiency scores, the organization should increase both its operating income and net income, by 114% and 192% respectively, followed by an increase in the percentage of total assets turnover by 95%.

The most inefficient organization, which obtained the lowest efficiency score (of 69.59% was VED. DEA indicates a potential increase in its operating income and net income by 232% and 167%, respectively, followed by an increase in the percentage of total assets turnover by 94%. These results are consistent with the nature of the return of scales (increasing the return to scale), as they show that the organization should consider expanding the scale of its operations.

5.5.1.5 Reference (Peer) Groups

Figure 5.18 represents the reference set frequency in the basic materials industry with a sample of 26 organizations, the global leader that most frequently appears in the reference set and the overall best performer is SXX, followed by RRS and CRDA. These organizations recur 6, 5 and 5 times respectively as part of the peer group over the total study analysis. Consequently, according to all types of efficiencies, the performance of this organization is better compared to the other efficient organizations in the sample.

Figure 5.18: Reference Set Frequency for basic materials industry in 2016



As there are multiple peers for each inefficient organization, the analysis of "reference contributions" provides further guidance on selecting a peer from the reference set of an inefficient unit for benchmarking purposes. Figure 5.19 shows that the reference set for ACA consists of six other efficient organizations, namely CRDA, ELM, ZTF, FXPO, RRS, and SXX. Figures 5.19 to 5.23 show the reference sets for organizations ACA, HOC, LMI, PDL, and VED.

Figure 5.19: ACA reference contribution

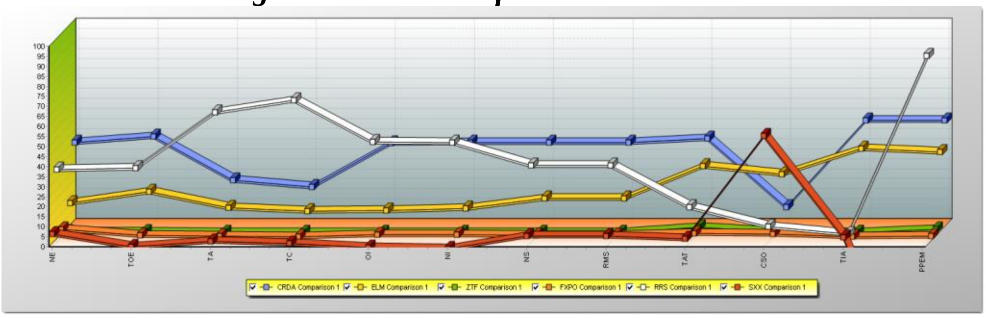


Figure 5.20: HOC reference contribution

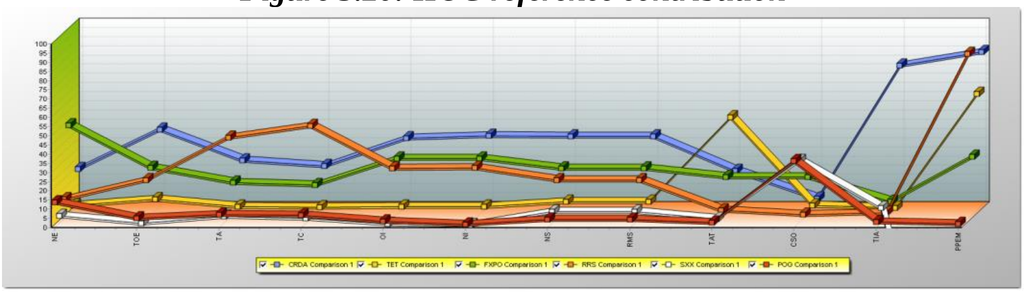


Figure 5.21: LMI reference contribution

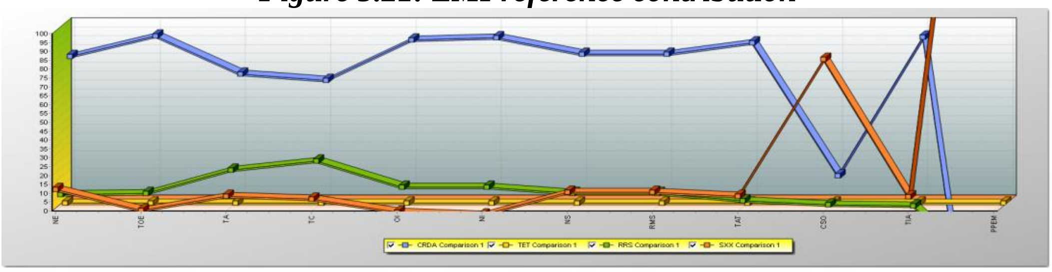


Figure 5.22: PDL reference contribution

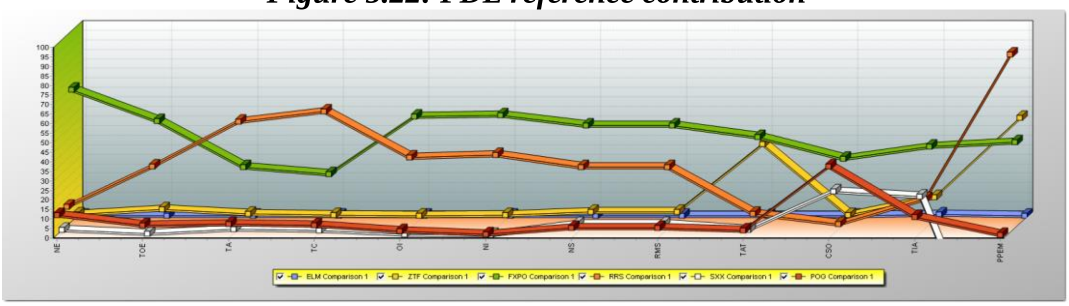
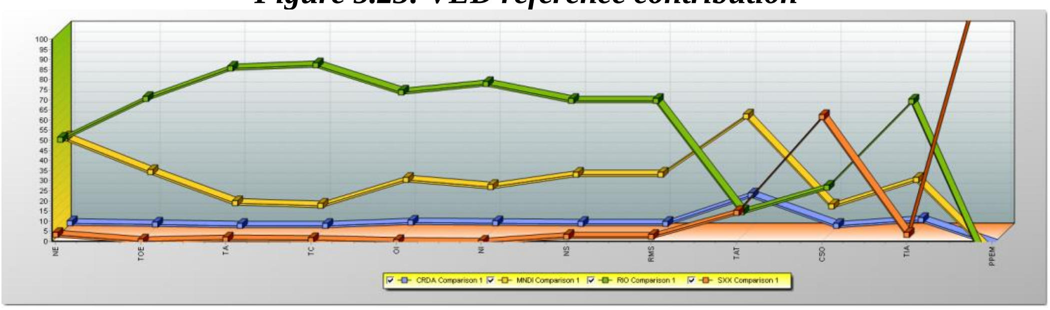


Figure 5.23: VED reference contribution



5.5.2 Malmquist Productivity Index Results

This section determines the efficiency scores of the twenty-six basic materials industry organizations in five different years (2016, 2015, 2014, 2013 and 2012) in terms of their ability to maximize their outputs using the same level of inputs by applying the combined DEA-BCC model. Hence, the results that are produced from this analysis show how the efficiency scores of the organizations changed during the period under consideration, and how different organizations operate relative to others.

Table 5.20: Efficiency scores in basic materials industry from 2012 to 2016

DMU	Efficiency Scores					Average
	2016	2015	2014	2013	2012	
AAL	100%	88%	88%	87%	87%	90%
ACA	92%	59%	73%	63%	80%	73%
ANTO	100%	100%	100%	100%	100%	100%
BLT	100%	100%	100%	100%	100%	100%
CAR	100%	100%	100%	100%	100%	100%
CRDA	100%	100%	100%	100%	100%	100%
ELM	100%	100%	100%	100%	100%	100%
EVR	100%	100%	100%	100%	100%	100%
FXPO	100%	75%	88%	88%	88%	88%
GEMD	100%	100%	100%	100%	100%	100%
GLEN	100%	100%	100%	100%	100%	100%
HOC	83%	40%	45%	53%	90%	62%
JMAT	100%	100%	100%	100%	100%	100%
KAZ	100%	64%	83%	64%	60%	74%
KMR	100%	100%	100%	100%	100%	100%
LMI	70%	61%	68%	73%	68%	68%
MNDI	100%	75%	88%	88%	88%	88%
PDL	89%	79%	88%	81%	88%	85%
POG	100%	87%	63%	64%	87%	80%
RIO	100%	100%	100%	100%	100%	100%
RRS	100%	100%	100%	100%	100%	100%
SXX	100%	100%	100%	100%	100%	100%
SYNT	100%	100%	100%	100%	100%	100%
TET	100%	100%	100%	100%	100%	100%
VED	88%	86%	84%	81%	74%	83%
No. of efficient DMUs	21	16	16	16	16	16

It can be clearly seen in Table 5.20 that there are few fluctuations within the efficiency scores achieved by the included organizations within the whole period, and according to the basic material industry, the status of the organizations included in the study became better by 2016. For instance, five organizations (AAL, FXPO, KAZ, MNDI, and POG) shifted from operating below average in 2012, 2013, 2014, and 2015 to efficient organizations with scores of 100% in 2016, and ACA shifted from operating below the average to operate above the average with an efficiency score of 92%.

The average efficiency score indicates that sixteen of twenty-one organizations are efficient, with efficiency scores of 100%, and that these organizations maintain their 100% efficiency scores within the whole examined period. These organizations are ANTO, BLT, CAR, CRDA, ELM, EVR, GEMD, GLEN, JMAT, KMR, RIO, RRS, SXX, SYNT, and TET.

5.6 Consumer Goods Industry

The consumer goods industry includes forty-two organizations from four sectors: Household Goods and Home Construction, Leisure Goods, Personal Goods, and Tobacco. The list of organizations' names, codes, and sectors which are adopted in the analysis of consumer goods are included in Appendix A, Table A.5.

5.6.1 BCC Model – Technical Efficiency

In order to evaluate the pure technical efficiency of the consumer goods industry, the BCC model will be applied and variable returns to scale will be examined.

5.6.1.1 Model Validation

The analysis will start with the model validation in order to check the validity of the applied BCC model. Each model will be operated with the target variables substituted in place of the actual variables. Table 5.21 represents the results of the BCC validation model. In each of the forty-two model runs, the substituted variables return an efficiency score of 100 percent as expected. These results validate both the model and target variables.

5.6.1.2 Efficiency scores

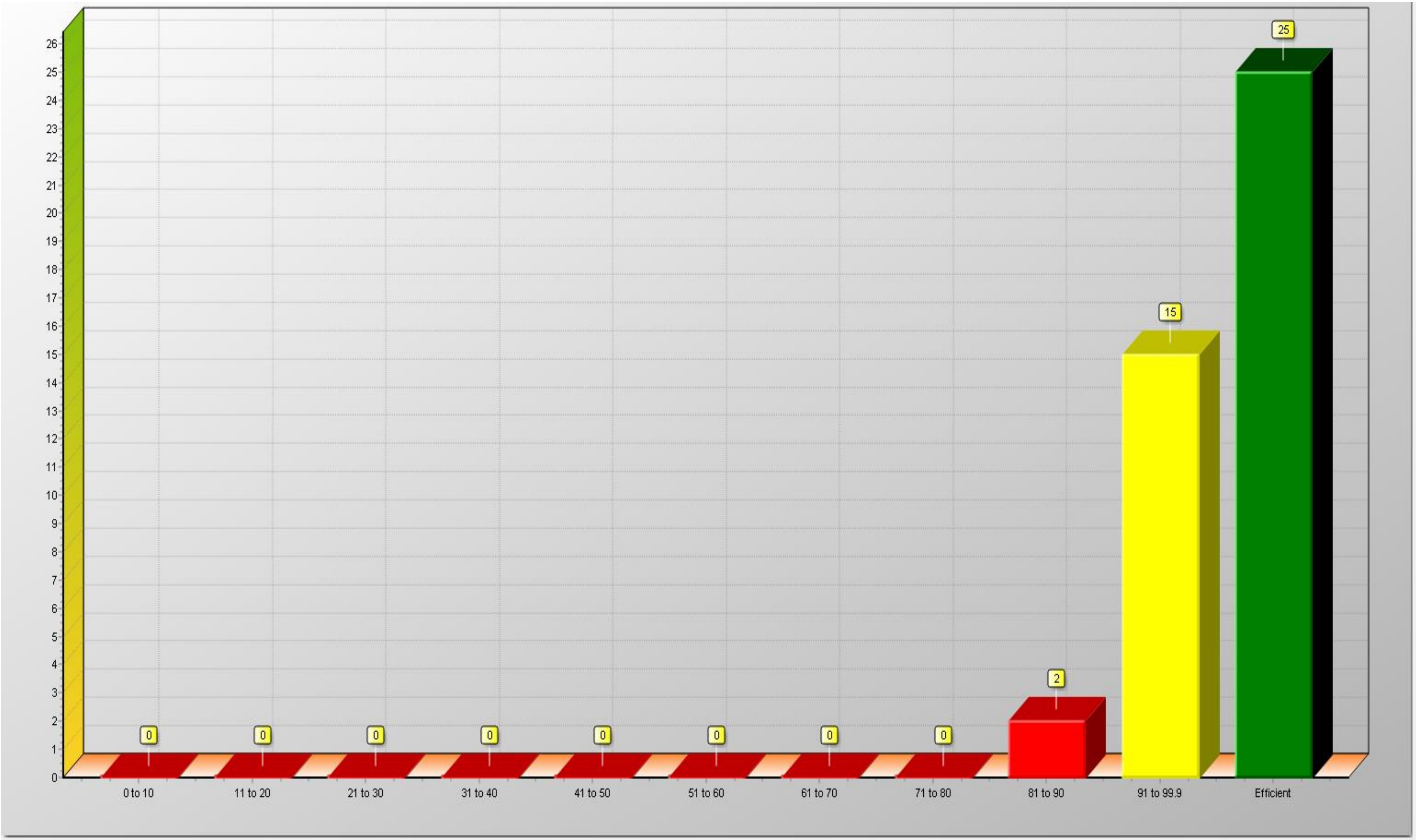
Based on the BCC model in Table 5.21, Figure 5.24 shows a graph presenting the technical efficiency scores and rankings for the forty-two organizations of the consumer goods industry. The graph shows that twenty-five of the forty-two organizations are efficient and obtain 100% efficiency scores. These organizations are shaded in green. Fifteen organizations are operating above average, which means that they are obtaining efficiency scores of over 90%: these organizations are shaded in yellow. Then only two organizations operating below average, with efficiency scores of less than 90%, are shaded in red.

Table 5.21: BCC Model Validation Results for consumer goods in 2016

NO.	DMU	**BCC model actual Result %**	Target NE	Target TOE	Target TA	Target TC	Target OI	Target NI	Target NS	Target RMS	Target TAT	Target CSO	Target TIA	Target PPEM	**VRS validation Result %**
1	DGE	100	31485	7516000	28193000	18464000	2969000	2244000	10485000	0.01	0.37	2517444	12370000	71.27	100
2	GLE	100	314	113899	176073	152905	28166	22959	142065	0	0.81	54120	10388	73.12	100
3	PSN	100	4526	2364800	4102100	2737400	772000	625300	3136800	0	0.76	308498	213600	138.16	100
4	RB.	100	34700	7119000	17938000	9230000	2772000	1832000	9891000	0.01	0.55	700076	13454000	52.8	100
5	ABF	100	129916	12359000	11237000	7762000	1040000	818000	13399000	0.02	1.19	791674	1382000	6.3	100
6	AEP	100	16772	139540	427920	383713	43588	25819	183129	0	0.43	39976	1145800	1.54	100
7	BDEV	100	6209	3566800	6418000	4181700	668400	550300	4235200	0.01	0.66	1003607	892200	88.63	100
8	BKG	100	2277	1545600	3766500	1812800	501900	404100	2047500	0	0.54	138257	17200	177.47	100
9	BLWY	100	2366	1748643	2718352	1867016	492008	402902	2240651	0	0.82	122686	17200	170.29	100
10	BRBY	100	10181	2111800	2179900	1620900	402900	309500	2514700	0	1.15	445037	189600	30.4	100
11	CHOO	100	1177	318100	808100	617500	45900	15400	364000	0	0.45	389738	607200	13.08	100
12	CRST	100	849	793200	1398200	922600	203800	156800	997000	0	0.71	254364	29000	184.69	100
13	GFRD	100	5696	2373000	1994000	774700	121900	108900	2494900	0	1.25	82872	152200	19.12	100
14	GKN	100	51381	8175000	8406000	3004000	647000	242000	8822000	0.01	1.05	1714474	1908000	4.71	100
15	GNCL	100	11856	1775418	1380360	742125	116701	60521	1892120	0	1.37	502766	637657	5.1	100
16	IMB	100	33900	11563000	32098000	18136000	2536000	631000	14099000	0.02	0.44	958711	20704000	18.61	100
17	PFD	100	3872	717200	2057800	1390300	54500	29200	771700	0	0.38	826567	1145800	7.54	100
18	STCK	100	876	181143	559272	413077	33101	23345	214244	0	0.38	200000	311047	26.65	100
19	ULVR	100	169000	36668927	47284091	24051820	6605283	4255753	43274210	0.06	0.92	2839690	23468383	25.18	100
20	UPGS	100	202	72342	27882	4078	6686	4898	79028	0	2.83	82170	20000	24.25	100
21	BATS	100	85335	9532000	39337000	24910000	5219000	4648000	14751000	0.02	0.37	1864374	12117000	54.47	100
22	GAW	100	86	107148	66644	53163	10921	13496	118069	0	1.77	32121	11934	156.93	100
23	HFG	100	2948	1203227	286154	112504	31268	24649	1234495	0	4.31	73552	8584	8.36	100

24	PHTM	100	1117	145495	186102	131933	38499	29066	183994	0	0.99	375479	20312	26.02	100
25	TW.	100	4673	2934500	4687800	2985800	741700	589300	3676200	0	0.78	3270272	3500	126.11	100
26	TED	99.46	1537	396800	334033	215970.2	61862.83	48301.92	458662.8	0	1.54	322723.8	24825.43	26.82	100
27	CWK	98.69	4788	1004811	510058	325379.8	78986.24	60213.5	1083797	0	2.91	174566.5	141527.4	13.84	100
28	TATE	98.3	4161	2047370	2551000	1541758	348287.6	250713.1	2395658	0	2.88	1274255	396733.1	54.55	100
29	MCB	98.22	1965	647300	309546.8	154500	45937.55	33511.43	693237.6	0	2.83	185510.5	97809.16	17.94	100
30	BRAG	97.73	1032	216300	269000	162224.9	48303.57	35330.57	264603.6	0	2.18	175970.1	109995.7	34.01	100
31	SGP	97.67	2093	531900	445100	285339.8	79860.97	62884.66	611761	0	1.77	291227.8	52729.19	27.79	100
32	HEAD	96.75	1818	652515	427636	209860	64367.7	46172.92	716882.7	0	3.37	90253.41	193821.4	20	100
33	BVIC	96.73	4358	1252600	1495218	774200	227110.5	155914.1	1479710	0	2.87	271762	891699.4	27.16	100
34	RDW	95	1866	1121000	2041000	1233733	333772.4	270883.7	1454772	0	1.21	389272.7	57948.27	154.83	100
35	PZC	94.11	2735	715900	981485.6	549900	156736.2	111532.9	872636.2	0	1.66	455578.4	447565.8	27.79	100
36	MCS	93.04	1344	539300	919800	613801	144136.4	113732.4	683436.4	0	0.87	577480.7	76630	64.03	100
37	CARR	92.96	905	302130	202153	117254	36629.85	28761.12	338759.9	0	2.55	156543.2	23305.35	25.31	100
38	CSP	92.8	1087	574050	909986	592057.3	149317.9	118676.3	723367.9	0	1.49	484933.6	63497.21	80.04	100
39	CCH	92.33	21594	4656454	5566951	3311958	872988.7	611936.8	5529443	0.01	1.12	615006.6	1897712	34.47	100
40	BVS	91.95	1186	894834	1628371	991964.6	252362.6	203484.3	1147197	0	1.05	146305.1	25729.47	170.91	100
41	DCG	89.51	1180	360300	645700	385800	111480.9	86375.13	471780.9	0	2.32	157175.8	182278.4	35.33	100
42	DVO	88.96	1550	203200	399400	267578.1	67827.15	54918.79	271027.2	0	0.98	382483.4	81002.28	26.74	100

Figure 5.24: Distribution of efficiency scores for consumer goods industry in 2016



The BCC model measures only managerial efficiency. This shows that from this perspective, the performance of more than half of the consumer goods organizations is efficient. As shown in Table 5.22, about 60% of organizations analysed are technically efficient. This reflects that the managerial teams have a significant role and a positive impact on the overall efficiency of their organizations. The implication of this is that there are greater efficiencies to be achieved in other areas: i.e. scale efficiencies.

Table 5.22: Efficiency score category for consumer goods industry at 2016

Efficiency score categories	**Number**	**Percentage**
Efficient (Equal to 100%)	25	60 %
Above average (Less than 100% and ≤ 90%)	15	36 %
Below average (Less than 90%)	2	4 %
Total	42	100%

Additionally, as shown in Table 5.21, fifteen organizations are performing above the average, with scores ranging between 99.46% and 91.95%, while two organizations are categorized as performing below the average, namely DCG and DVO, with efficiency scores of 89.51% and 88.96% respectively.

5.6.1.3 Return to scale

Table 5.23 shows technical efficiency decomposed into pure technical efficiency and scale efficiency. Technical efficiency scores are obtained from a CRS run, whereas pure technical efficiency scores are generated through a VRS run. The last column identifies the returns to scale prevailing in each DMU at the time of measurement.

Table 5.23: Returns to Scale for consumer goods industry in 2016

NO	DMU	**Technical Efficiency** %	**Pure Technical Efficiency** %	**Scale Efficiency** %	**Returns to Scale**
1	ABF	90.84	100	90.84	Increasing returns
2	AEP	100	100	100	Constant
3	BATS	100	100	100	Constant
4	BDEV	92.44	100	92.44	Increasing returns
5	BKG	100	100	100	Constant
6	BLWY	100	100	100	Constant
7	BRAG	96.93	97.73	99.18	Increasing returns
8	BRBY	98.22	100	98.22	Increasing returns
9	BVIC	93.35	96.73	96.51	Increasing returns
10	BVS	91.78	91.95	99.82	Decreasing returns
11	CARR	91.2	92.96	98.11	Increasing returns

12	CCH	88.75	92.33	96.12	Increasing returns
13	CHOO	100	100	100	Constant
14	CRST	100	100	100	Constant
15	CSP	92.5	92.8	99.68	Decreasing returns
16	CWK	95.39	98.69	96.66	Increasing returns
17	DCG	89.08	89.51	99.52	Decreasing returns
18	DGE	100	100	100	Constant
19	DVO	88.63	88.96	99.63	Decreasing returns
20	GAW	100	100	100	Constant
21	GFRD	91.87	100	91.87	Increasing returns
22	GKN	92.47	100	92.47	Increasing returns
23	GLE	99.71	100	99.71	Decreasing returns
24	GNCL	91.8	100	91.80	Increasing returns
25	HEAD	93.05	96.75	96.18	Increasing returns
26	HFG	100	100	100	Constant
27	IMB	100	100	100	Constant
28	MCB	92.89	98.22	94.57	Increasing returns
29	MCS	92.86	93.04	99.81	Decreasing returns
30	PFD	90.83	100	90.83	Increasing returns
31	PHTM	100	100	100	Constant
32	PSN	100	100	100	Constant
33	PZC	90.96	94.11	96.65	Increasing returns
34	RB.	100	100	100	Constant
35	RDW	94.81	95	99.80	Decreasing returns
36	SGP	95.25	97.67	97.52	Increasing returns
37	STCK	100	100	100	Constant
38	TATE	89.06	98.3	90.60	Increasing returns
39	TED	97.4	99.46	97.93	Increasing returns
40	TW.	100	100	100	Constant
41	ULVR	96	100	96.00	Increasing returns
42	UPGS	100	100	100	Constant

The results in Table 5.23 show that overall and pure technical efficiency scores for sixteen of the forty-two organizations are the same, at 100%, which in return proves that they are operating efficiently and are at their optimal size, or in other words, they have no scale effects.

Some organizations achieved 100% technical efficiency scores, but their overall efficiency was less than 100% due to scale inefficiency. These organizations are ABF, BDEV, BRBY, GFRD, GKN, GNCL, and ULVR. They are also similar in that they are obtaining an increasing return to scale, which reflects that in order to achieve a 100% overall efficiency score, they should expand the scale of their operations in order to benefit from higher productivity. In contrast, one organization has a 100% technical efficiency score but overall efficiency of

97.71% due to scale inefficiency. It is obtaining a decreasing return to scale: hence, it is required to downsize its operations in order to achieve 100% overall efficiency. The remaining organizations are inefficient either in technical efficiency or scale efficiency.

5.6.1.4 Potential improvements

Once the inefficient organizations had been determined, in order to assist managers to determine aspects of deficiency and take decisions to deal with this situation, DEA provides the potential improvements that the inefficient organizations can follow to be efficient. Since the most efficient organizations are operating in the same environment, the inefficient organizations could enhance their performances by choosing the same policies and managerial structures as their respective peer (reference) organizations. For the efficient organizations, there are no changes to the actual values of their variables. Thus, Table 5.24 shows the potential improvements for each inefficient organization. Additionally, the table represents the reference set for each unit.

For clarity in discussing the results, the researcher will discuss the potential improvements for the organizations operating below the average and will consider only two organizations operating above the average with the lowest efficiency score within this category. The potential improvements for the remaining organizations will be included in Appendix B, Table B.1.

Table 5.24: Potential improvements in consumer goods industry in 2016

Category	**Variable**	**DVO (Efficiency: 88.96%)**	**DCG (Efficiency: 89.51%)**	**BVS (Efficiency: 91.95%)**	**CCH (Efficiency: 92.33%)**
Input	NE	0%	0%	0%	0%
	TOE	0%	0%	0%	0%
	TA	0%	0%	0%	0%
	TC	0%	0%	0%	0%
Financial	OI	79%	80%	58%	94%
	NI	139%	176%	68%	117%
Customer	NS	179%	187%	117%	118%
	RMS	253%	137%	201%	280%
Internal process	TAT	23%	25%	31%	22%
	CSO	29%	12%	9%	30%
Learning and growth	TIA	12%	12%	9%	8%
	PPEM	12%	12%	9%	8%
	Reference set	PSN PHTM BATS	RB., PHTM PSN, BATS BKG, UPGS	PSN, BKG BLWY CRST GAW	PSN ULVR BRBY

Table 5.24 shows that the consumer goods industry is different from the previous industries (technology, oil and gas, health care, and basic materials) in that the customer perspective measures (net sales and relative market share) of the BSC play a dominant role in the improvements suggested by the DEA. On the other hand, the consumer goods industry is similar to the technology, oil and gas, health care, and basic materials industries in that the financial perspective indicator (net income) plays a significant role in achieving the target efficiency score. The other perspectives of the BSC (learning and growth and internal processes) have a slight effect on the efficiency scores.

For instance, organization CCH is considered to have above-average performance, with an efficiency score of 92.33%, and obtaining increasing returns to scale. The results show that the potential improvements in order to achieve an 100% efficiency score are that the organization should increase its relative market share, net sales and net income by 280%, 118%, and 117%, followed by an increase in operating income by 94%.

The most inefficient organization, which obtained the lowest efficiency score (88.96%), is DVO. For this organization, DEA indicates a potential increase in the relative market share, net sales and net income by 253%, 179%, and 139% respectively, followed by an increase in the operating income by 79%.

5.6.1.5 Reference (Peer) Groups

Figure 5.25 represents the reference set frequency in the consumer goods industry with a sample of forty-two organizations. The global leader that most frequently appears in the reference set and the overall best performer are PSN and PHTM: these organizations recur twelve times as part of the peer group over the total study analysis. Consequently, according to all types of efficiencies, the performance of these organizations is better compared to the other efficient organizations in the sample.

As there are multiple peers for each inefficient organization, the analysis of “reference contributions” provides further guidance on selecting a peer from the reference set of an inefficient unit for benchmarking purposes. Figure 5.26 shows that the reference set for the DVO organization consists of three other efficient organizations, namely PSN, PHTM, and BATS. Figures 5.27 to 5.29 show the reference set for the organizations DCG, BVS, and CCH.

Figure 5.25: Reference Set Frequency for consumer goods industry in 2016

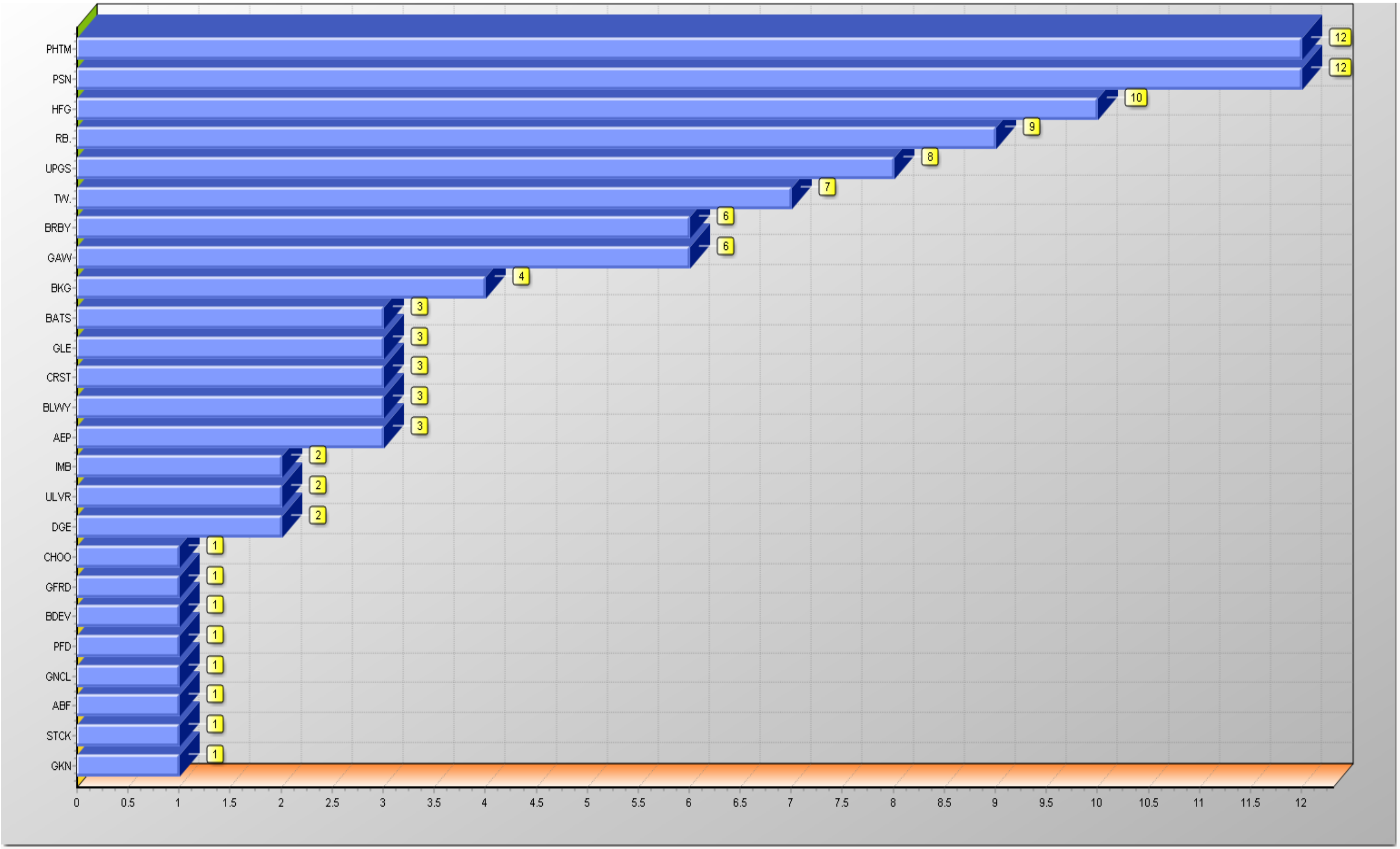


Figure 5.26: DVO reference contribution

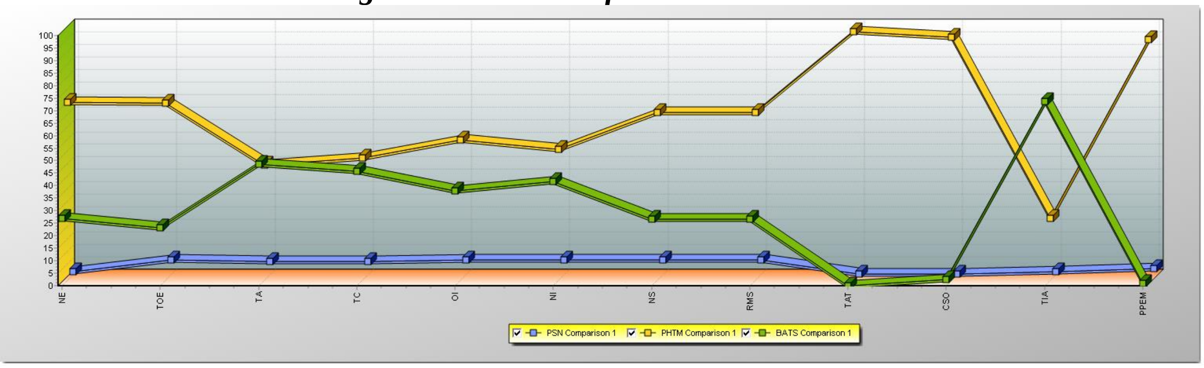


Figure 5.27: DCG reference contribution

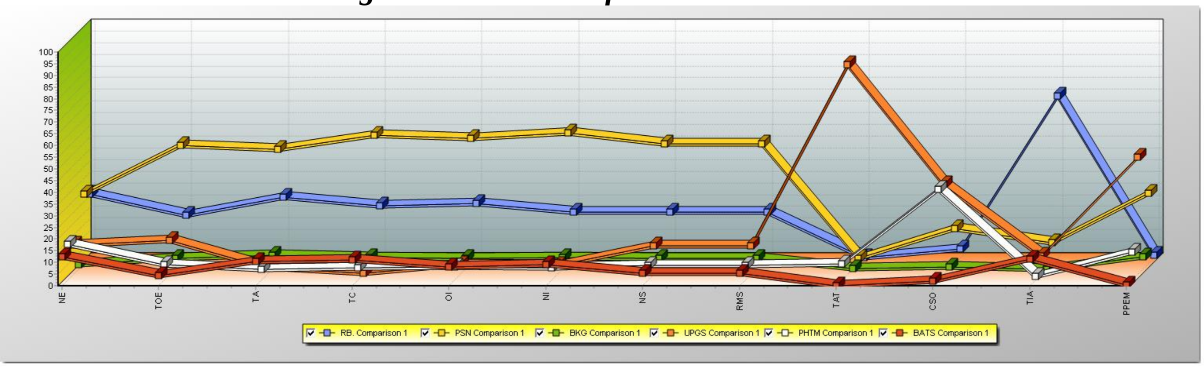


Figure 5.28: BVS reference contribution

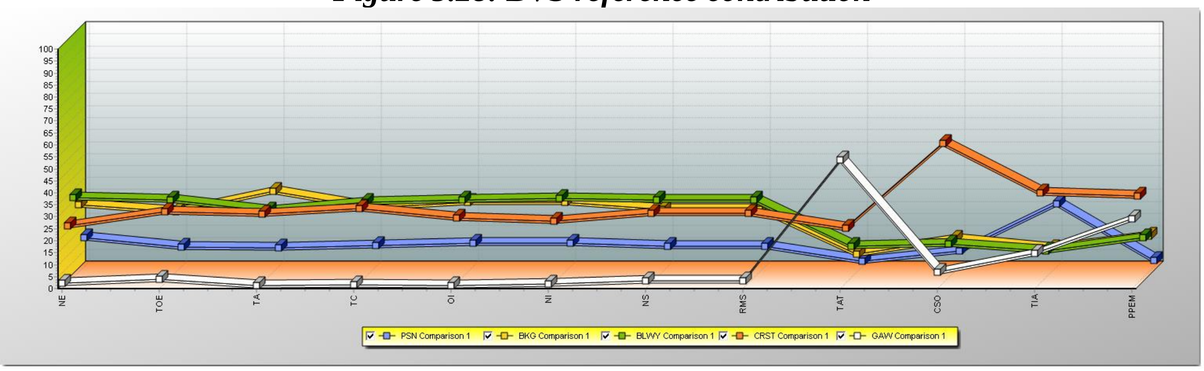
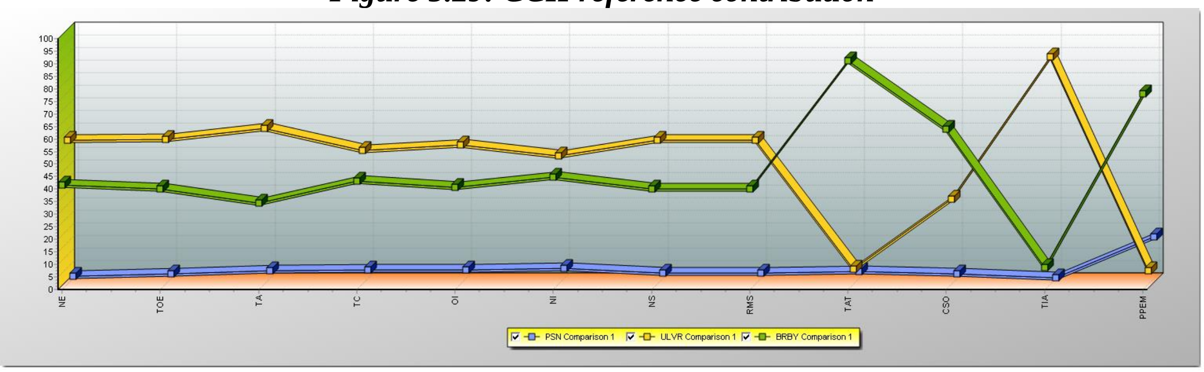


Figure 5.29: CCH reference contribution



5.5.2 Malmquist Productivity Index Results

This section determines the efficiency scores of the forty-two consumer goods industry organizations in five different years (2016, 2015, 2014, 2013 and 2012), in terms of their ability to maximize their outputs using the same level of inputs by applying the combined DEA-BCC model. Hence, the results that are produced from this analysis show how the efficiency scores of the organizations changed during the period under consideration, and how different organizations operate relatively to others.

Table 5.25: Efficiency scores in consumer goods industry from 2012 to 2016

DMU	Efficiency Scores					Average
	2016	2015	2014	2013	2012	
ABF	100%	100%	100%	100%	100%	100%
AEP	100%	100%	100%	100%	100%	100%
BATS	100%	100%	100%	100%	100%	100%
BDEV	100%	100%	100%	100%	100%	100%
BKG	100%	100%	100%	100%	100%	100%
BLWY	100%	100%	100%	100%	100%	100%
BRAG	97%	97%	97%	97%	97%	97%
BRBY	100%	100%	100%	100%	100%	100%
BVIC	97%	97%	99%	99%	97%	98%
BVS	92%	92%	96%	92%	92%	93%
CARR	93%	96%	96%	96%	97%	95%
CCH	92%	90%	92%	90%	90%	91%
CHOO	100%	100%	100%	100%	100%	100%
CRST	100%	100%	100%	100%	100%	100%
CSP	93%	94%	91%	93%	97%	94%
CWK	99%	97%	97%	96%	96%	97%
DCG	89%	89%	93%	91%	94%	91%
DGE	100%	100%	100%	100%	100%	100%
DVO	89%	86%	93%	93%	98%	91%
GAW	100%	100%	100%	100%	100%	100%
GFRD	100%	100%	100%	100%	100%	100%
GKN	100%	100%	100%	100%	100%	100%
GLE	100%	100%	100%	100%	100%	100%
GNCL	100%	100%	100%	100%	100%	100%
HEAD	95%	97%	95%	93%	95%	95%
HFG	100%	100%	100%	100%	100%	100%
IMB	100%	100%	100%	100%	100%	100%
MCB	98%	98%	96%	96%	96%	97%
MCS	98%	98%	96%	96%	96%	97%
PFD	100%	100%	100%	100%	100%	100%
PHTM	100%	100%	100%	100%	100%	100%
PSN	100%	100%	100%	100%	100%	100%
PZC	94%	95%	91%	91%	92%	93%

RB.	100%	100%	100%	100%	100%	100%
RDW	97%	99%	100%	100%	100%	99%
SGP	97%	94%	100%	100%	100%	98%
STCK	100%	100%	100%	100%	100%	100%
TATE	98%	97%	100%	100%	100%	99%
TED	99%	97%	97%	97%	96%	97%
TW.	100%	100%	100%	100%	100%	100%
ULVR	100%	100%	100%	100%	100%	100%
UPGS	100%	100%	100%	100%	100%	100%
No. of efficient DMUs	25	25	27	27	27	25

Generally speaking, Table 5.25 shows that the consumer goods industry is considered stable. Thirty-eight of the forty-two organizations are considered to be stable in their status and maintaining their efficiency condition. However, during the whole period, four organizations showed negative shifts in 2015 and 2016. RDW and SGP shifted from efficient organizations, both with an efficiency score of 100%, in 2012, 2013, and 2014, to operating above the average between 2015 and 2016. Similarly, DCG and DVO shifted from operating above the average in 2012, 2013, and 2014 to operate below the average between 2015 and 2016.

The average efficiency score indicates that twenty-five of these forty-two organizations are efficient, with efficiency scores of 100%, and that these organizations maintain their 100% efficiency scores within the whole of the period examined.

5.7 Consumer Services Industry

The consumer services industry includes eighty-seven organizations from four sectors: Food and Drug Retailers, General Retailers, Media, and Travel and Leisure. The list of organizations' names, codes, and sectors which are adopted in the analysis of the consumer services industry are included in Appendix A, Table (A.6).

5.7.1 BCC Model – Technical Efficiency

In order to evaluate the pure technical efficiency of the consumer services industry, the BCC model will be applied and variable returns to scale will be examined.

5.7.1.1 Model Validation

The analysis will start with the model validation to check the validity of the applied BCC model, each model operated with the target variables substituted in place of the actual variables. Table 5.26 presents the results of the BCC validation model. In each of the eighty-seven model runs, the substituted variables return an efficiency score of 100%, as expected. These results validate both the model and target variables.

5.7.1.2 Efficiency scores

Based on the BCC model in Table 5.26, Figure 5.30 shows the technical efficiency scores and rankings for the eighty-seven organizations of the consumer services industry. The graph shows that thirty-five of these organizations are efficient and obtain 100% efficiency scores. These organizations are shaded in green. Furthermore, sixteen organizations are operating above average, with efficiency scores of 90% or above: these organizations are shaded in yellow. The remaining thirty-five organizations are operating below average, with efficiency scores less than 90%, and are shaded in red.

Figure 5.30: Distribution of efficiency scores for consumer services industry in 2016

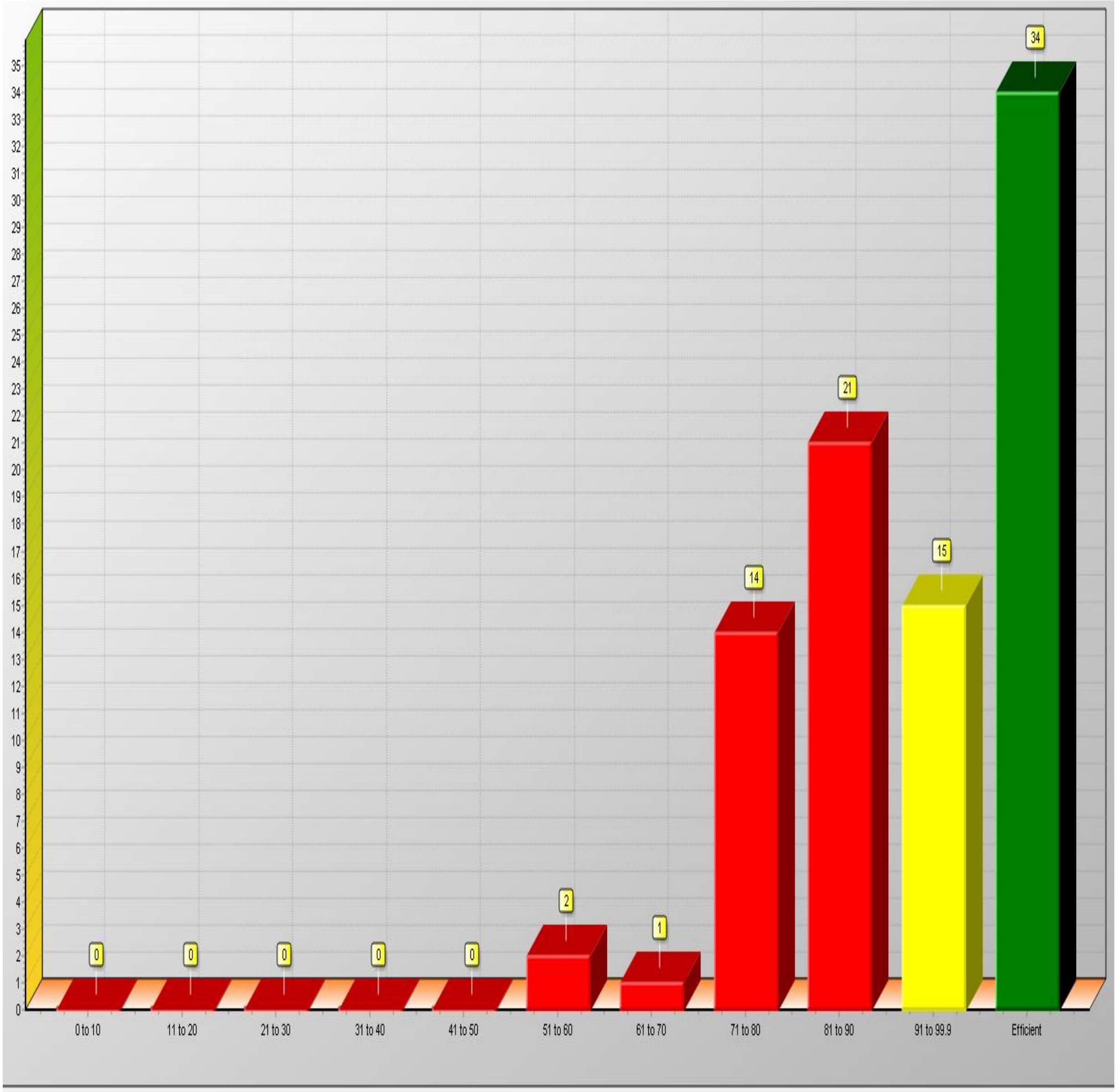


Table 5.26: BCC Model Validation Results for consumer services industry in 2016

NO.	DMU	**BCC model actual Result %**	Target NE	Target TOE	Target TA	Target TC	Target OI	Target NI	Target NS	Target RMS	Target TAT	Target CSO	Target TIA	Target PPEM	**VRS validation Result %**
1	AO.	100	2101	609800	166400	53200	-10600	-6000	599200	0	3.6	421053	15600	-2.86	100
2	GYM	100	235	65472	158952	123468	8067	5703	73539	0	0.46	128105	48717	24.27	100
3	TSCO	100	475399	53489000	43855000	19327000	944000	138000	54433000	0.07	1.24	8141083	2874000	0.29	100
4	AUTO	100	859	112000	393200	344100	169600	126700	281600	0	0.72	1001052	323400	147.5	100
5	CCL	100	97200	9757965	31148800	24763200	2251894	2036451	12009859	0.02	0.39	726000	3348000	20.95	100
6	DC.	100	45202	9306000	6695000	3358000	432000	161000	9738000	0.01	1.45	1151000	3594000	3.56	100
7	FOUR	100	852	386928	69488	23783	28272	18207	415201	0	5.98	28086	1878	21.37	100
8	GOCO	100	172	120200	39400	4800	21900	15800	142100	0	3.61	418258	3000	91.86	100
9	HSW	100	241	59004	145377	136822	7093	644	66097	0	0.45	95571	119441	2.67	100
10	IHT	100	6587	754947	2334869	686917	520653	307929	1275600	0	0.55	189112	1047812	46.75	100
11	INCH	100	14895	7505600	4349400	1654500	332800	184400	7838400	0.01	1.8	421005	614500	12.38	100
12	INF	100	6559	1045800	4998500	3548300	299900	171600	1345700	0	0.27	824005	4479400	26.16	100
13	ITV	100	6121	2296000	3566000	1790000	768000	443000	3064000	0	0.86	4025409	1655000	72.37	100
14	JD.	100	12602	1663992	790814	401099	157660	97634	1821652	0	2.3	973233	73611	7.75	100
15	LCL	100	26141	1415900	3384000	2186800	92000	-204300	1507900	0	0.45	1914449	2663300	-7.82	100
16	LOOK	100	9081	3987400	1707800	430500	100800	81300	4088200	0.01	2.39	396542	217400	8.95	100
17	MORW	100	120913	15890000	9299000	5759000	232000	221800	16122000	0.02	1.73	2335154	483000	1.83	100
18	NXT	100	30591	3301000	2327400	926800	875900	666800	4176900	0.01	1.79	150670	43700	21.8	100
19	OTB	100	315	54499	148657	82138	16822	14307	71321	0	0.48	130435	64662	45.42	100
20	PDG	100	9656	4435800	1857400	548500	101200	55500	4537000	0.01	2.44	1436897	362200	5.75	100
21	RMV	100	469	58346	53512	8042	161647	129542	219993	0	4.11	93219	3525	276.21	100
22	SKY	100	27941	10988000	17165000	12342000	977000	666000	11965000	0.02	0.7	1719017	9195000	23.84	100
23	STVG	100	128	103500	72300	-13300	16900	12600	120400	0	1.67	39548	2700	450	100

24	TRS	100	433	58716	271816	155439	9642	7091	68358	0	0.25	112785	186813	16.38	100
25	TUI	100	77028	16527200	14113200	4751600	657400	1037400	17184600	0.02	1.22	587038	3399300	13.47	100
26	UBM	100	3852	682600	2610700	1912000	180400	491500	863000	0	0.33	393909	2200300	127.6	100
27	WPP	100	198000	12443700	34427900	15332500	1945200	1400100	14388900	0.02	0.42	1280854	1543160	7.07	100
28	ZPG	100	599	136649	373002	291923	61079	36678	197728	0	0.53	417954	322621	61.23	100
29	CPG	100	527180	18208000	10393000	5595000	1663000	992000	19871000	0.03	1.91	1579895	5519000	1.88	100
30	ETO	100	1529	731100	1623500	969500	71600	36500	802700	0	0.49	427343	808200	23.87	100
31	MOTR	100	661	713200	111200	25700	16000	13400	729200	0	6.56	100000	104330	20.27	100
32	REL	100	31200	5224000	12879000	6042000	1671000	1161000	6895000	0.01	0.54	2042700	9996000	37.21	100
33	SBRY	100	162700	22813000	16973000	8736000	693000	459000	23506000	0.03	1.38	1924077	329000	2.82	100
34	TCG	100	21940	7482000	6727000	1379000	330000	12000	7812000	0.01	1.16	1535851	3077000	0.55	100
35	BOK	100	13144	4836400	1360400	590200	155100	127800	4991500	0.01	3.67	1772837	466700	9.72	100
36	MKS	98.25	80041	9839900	8476400	3895363	903197.3	606125.7	10743097	0.01	1.48	1651825	1254264	25.23	100
37	MONY	97.58	598	223097	209230.2	155892.6	101175.2	76768.66	324272.2	0	2.93	561289.1	161539.1	133.53	100
38	BME	97.57	22929	1855728	1564430	910133.9	230172.2	149357.8	2085900	0	1.33	1024869	961966.5	101.05	100
39	SMWH	97.46	5341.82	1081000	461000	167219.9	162631.5	125152.1	1243631	0	5.58	115949.1	87755.29	42.89	100
40	KGF	97.16	74000	9778000	9683000	4724631	968392.3	637402.8	10746392	0.01	1.14	2363592	2751183	34.52	100
41	DNLM	96.07	2985	751900	345800	109153.9	165047.3	128263.5	916947.3	0	4.38	210252.5	57939.59	182.92	100
42	EZJ	96.06	10273	4113891	5505000	3176167	746553.5	444508.4	4860444	0.01	0.96	3249398	2566350	58.12	100
43	GOG	94.84	12907	3265500	1571900	511800	278844.2	205238.2	3544344	0	3.17	656698.9	202590.4	13.49	100
44	WMH	94.7	16286	1365000	2439900	1430700	328534.1	221536.2	1693534	0	1.59	936894.6	1906308	93.88	100
45	TNI	93.6	3256	579400	1290812	579400	234821.9	170493.9	814221.9	0	2.8	302843.3	963145.5	293.74	100
46	SSPG	93.42	29942	1870800	1327300	661322.5	259758	180210.2	2130558	0	4.15	508686.6	750721.2	52.11	100
47	PETS	92.23	5474	690863	1251905	823064.9	169064.9	116119.7	859927.9	0	2.9	655672.1	1055547	78.47	100
48	DFS	91.64	3923	680200	687400	365071.2	144743	105569	824943	0	4.11	484139.4	535994.7	85.33	100
49	JE.	91.15	1587	288000	1034000	771257.6	146131.3	98932.56	434131.3	0	0.92	744399	909077.4	96.17	100
50	MCLS	90.98	9760	951195	329791	136956.3	93379.31	68865.93	1044574	0	5.89	126585	169645	66.72	100

51	WTB	90.71	18381	2371300	4405300	1809056	849727.6	579620.2	3221028	0	0.91	542319.2	2515691	37.64	100
52	HFD	89.97	11036	936600	704900	322612.4	198722.8	147371.8	1135323	0	4.75	221304	403336.9	132.05	100
53	SGC	89.75	32010.	3679300	2242200	885545.5	633733.5	467677.1	4313033	0.01	1.98	639767.6	251355	17.25	100
54	WIZZ	89.02	2250	875842	1054374	503105.9	302035.6	196048.4	1177878	0	3.55	1112156	454249.7	184.66	100
55	DOM	88.86	911	277445	250238	164138	128320.5	97963.89	405765.5	0	2.79	561168.1	153892.4	163.11	100
56	GREG	87.76	4898	813850	414224	149983.9	205064.4	159361.5	1018914	0	4.73	115264.9	52019.49	136.78	100
57	DEB	87.67	27893	2210700	2170900	1083600	460213.9	310900.4	2670914	0	1.31	1400437	1097359	103.58	100
58	SAGA	87.16	3935	768200	2379268	1487234	336879.2	207896.6	1105079	0	0.59	1282687	1763744	90.03	100
59	SPD	87.02	18280	2641525	2315872	1009921	695919.6	492201.9	3337445	0	1.98	1130691	468065.6	80.22	100
60	CARD	87.01	1931	296200	455900	358286.5	142370.3	105009.6	438570.3	0	1.96	804621.8	380416.1	117.15	100
61	ERM	86.48	1491	318399	768353	477511	147730.7	108129.8	466129.7	0	3.78	278372.9	637297.5	174.28	100
62	FGP	86.31	76625	4969000	5274700	2484737	1076732	744040.8	6045732	0.01	1.4	1395856	2692888	32.46	100
63	MERL	85.07	6338	1137000	2613727	969240.6	575784.3	338233.2	1712784	0	0.63	1194140	1195540	55.54	100
64	GKN	84.97	11686	1680800	4519295	1796329	758970.2	484659.6	2439770	0	0.54	573119.5	2901607	44.77	100
65	OCDO	84.77	10930	1301300	686400	333784.2	197974.9	137971	1499275	0	2.67	703478.4	94014.33	92.39	100
66	ASCL	84.23	1312	246800	879400	647400	108891.1	70069.94	355691.1	0	0.92	512243.8	773592.4	82.57	100
67	RNK	83.7	10567	626100	713300	385202	220360.4	162792.6	846460.4	0	3.14	466758.7	483026	191.58	100
68	MTC	83.22	2046	659300	327100	89100	160603.8	123946.8	819903.8	0	3.87	265680	64770.36	239.84	100
69	MAB	81.82	12166	1768000	4725032	1900817	781415.7	501304.7	2549416	0	0.54	609286.7	3076203	44.59	100
70	RTN	81.15	5535	631556	422191	177923.3	244209.4	187705.7	875765.4	0	3.47	247757.2	32571.71	208.64	100
71	ITE	80.9	570	117533	287995	170966	48628.54	35678.94	166161.5	0	1.76	324036.2	208497.4	72.68	100
72	NEX	80.5	14239	1918500	3386600	1430665	694657	480065.5	2613157	0	1.8	635667.8	1923627	102.08	100
73	JDW	80.13	13631	1485470	1313285	483814	505370.5	374719.7	1990841	0	2.65	141843.9	172311.2	139.46	100
74	PSON	79.29	28418	4354000	9615000	4433379	1386615	969326.4	5740615	0.01	0.79	1461433	7025078	35.14	100
75	BOWL	79.19	324	87836	136368	103766	46814.44	33541.53	134650.4	0	1.95	189413.8	100045.8	82.14	100
76	CINE	78.62	5869	689800	1296700	603112.3	324952.9	242071.3	1014753	0	3.42	340346.7	896462.5	233.78	100
77	BRWN	78.07	2939	804200	920100	424720.8	305280	208283.2	1109480	0	3.35	853617.5	337022.3	221.52	100

78	HNT	76.61	536.03	163128	253283	197731	72018.99	50508.9	235147	0	1.73	428978.8	208595.6	84.52	100
79	MARS	76.33	5073	733100	1950966	701406.2	453543.2	273969.4	1186643	0	0.62	753802.7	918317.5	74.98	100
80	CPR	76.2	3239	439400	237000	76200	160061.7	124710.8	599461.7	0	4.12	183347.3	74932.71	245.85	100
81	DTY	73.29	1680	211800	715000	442477.2	216089.6	150868.8	427889.6	0	0.69	903964.7	488607.3	133.54	100
82	SPO	73.22	401	83700	197800	148800	50954.1	36184.12	134654.1	0	1.32	281651	149676.4	71.33	100
83	MLC	72.34	6077	777000	2231190	712674.8	503139.7	299255	1280140	0	0.58	448928.1	1016487	56.58	100
84	TPT	72.01	1102	193921	94467	31256.72	104660.2	81450.78	298581.2	0	3.86	272416.5	9669.14	183.6	100
85	FDL	68.41	1715	375924	410024	177960.8	224295.1	165328.3	600219.1	0	3.79	388789	133076.2	252.63	100
86	MOSB	53.22	404	115148	55296	9683.35	112324.4	89310.34	227472.4	0	4.11	189385	9407.07	205.8	100
87	BMY	51.72	552	112395	173646	131624.8	126820.2	98025.33	239215.2	0	2.58	360582	124817.3	172.76	100

The BCC model measures only managerial efficiency. It shows that more than half the consumer services organizations is inefficient. As shown in Table 5.27, about 40% of the organizations analysed are technically efficient. This reflects that the managerial teams of these organizations have a significant role and positive impact on the overall efficiency of their organizations. The implication of this is that there are greater efficiencies to be achieved in other areas: i.e. scale efficiencies.

Table 5.27: Efficiency score category for consumer services industry in 2016

Efficiency score categories	**Number**	**Percentage**
Efficient (Equal to 100%)	35	40 %
Above average (Less than 100% and ≤ 90%)	16	18 %
Below average (Less than 90%)	36	42 %
Total	87	100%

Furthermore, the results set out in Table 5.26 showed that a high percentage of organizations are technically inefficient, with efficiency scores ranging between 89.97% and 51.72%. Additionally, sixteen organizations are performing above the average, with scores ranging between 98.25% and 90.71%.

5.7.1.3 Return to scale

Table 5.28 shows technical efficiency decomposed into pure technical efficiency and scale efficiency. Technical efficiency scores are obtained from a CRS run, whereas pure technical efficiency scores are generated through a VRS run. The last column identifies the returns to scale prevailing in each DMU at the time of measurement.

The results from Table 5.28 show that the overall efficiency and pure technical efficiency scores for eleven of the eighty-seven organizations are the same, at 100%, which proves that they are operating efficiently and are at their optimal size: in other words, they have no scale effects.

Table 5.28: Returns to Scale for consumer services industry in 2016

NO	DMU	**Technical Efficiency %**	**Pure Technical Efficiency %**	**Scale Efficiency %**	**Returns to Scale**
1	AO.	72.53	100	72.53	Increasing returns
2	ASCL	83.85	84.23	99.55	Decreasing returns
3	AUTO	100	100	100	Constant
4	BME	75.42	97.57	77.30	Increasing returns
5	BMY	50.92	51.72	98.45	Decreasing returns
6	BOK	71.93	100	71.93	Increasing returns
7	BOWL	71.67	79.19	90.50	Decreasing returns
8	BRWN	53.62	78.07	68.68	Increasing returns
9	CARD	85.73	87.01	98.53	Increasing returns
10	CCL	36.42	100	36.42	Increasing returns
11	CINE	66.2	78.62	84.20	Increasing returns
12	CPG	74.76	100	74.76	Increasing returns
13	CPR	54.02	76.2	70.89	Increasing returns
14	DC.	72.65	100	72.65	Increasing returns
15	DEB	63.76	87.67	72.73	Increasing returns
16	DFS	84.94	91.64	92.69	Increasing returns
17	DNLM	55.27	96.07	57.53	Increasing returns
18	DOM	68.58	88.86	77.18	Increasing returns
19	DTY	61.3	73.29	83.64	Increasing returns
20	ERM	85.85	86.48	99.27	Decreasing returns
21	ETO	100	100	100	Constant
22	EZJ	70.11	96.06	72.99	Increasing returns
23	FDL	46.25	68.41	67.61	Increasing returns
24	FGP	53.18	86.31	61.62	Increasing returns
25	FOUR	100	100	100	Constant
26	GKN	41.5	84.97	48.84	Increasing returns
27	GOCO	100	100	100	Constant
28	GOG	46.84	94.84	49.39	Increasing returns
29	GREG	47.83	87.76	54.50	Increasing returns
30	GYM	67.54	100	67.54	Decreasing returns
31	HFD	70.31	89.97	78.15	Increasing returns
32	HNT	74.46	76.61	97.19	Decreasing returns
33	HSW	94.29	100	94.29	Decreasing returns
34	IHT	93.77	100	93.77	Increasing returns
35	INCH	72.78	100	72.78	Increasing returns
36	INF	100	100	100	Constant
37	ITE	76.71	80.9	94.82	Decreasing returns
38	ITV	92.76	100	92.76	Increasing returns
39	JD.	51.71	100	51.71	Increasing returns
40	JDW	29.93	80.13	37.35	Increasing returns
41	JE.	91.11	91.15	99.96	Decreasing returns
42	KGF	47.44	97.16	48.83	Increasing returns
43	LCL	93.11	100	93.11	Increasing returns
44	LOOK	66.16	100	66.16	Increasing returns
45	MAB	31.29	81.82	38.24	Increasing returns

46	MARS	36.76	76.33	48.16	Increasing returns
47	MCLS	72.64	90.98	79.84	Increasing returns
48	MERL	44.21	85.07	51.97	Increasing returns
49	MKS	35.57	98.25	36.20	Increasing returns
50	MLC	32.96	72.34	45.56	Increasing returns
51	MONY	97.57	97.58	99.99	Decreasing returns
52	MORW	39.44	100	39.44	Increasing returns
53	MOSB	51.32	53.22	96.43	Increasing returns
54	MOTR	100	100	100	Constant
55	MTC	50.16	83.22	60.27	Increasing returns
56	NEX	59.87	80.5	74.37	Increasing returns
57	NXT	42.11	100	42.11	Increasing returns
58	OCDO	44.26	84.77	52.21	Increasing returns
59	OTB	67.81	100	67.81	Decreasing returns
60	PDG	67.9	100	67.90	Increasing returns
61	PETS	88.51	92.23	95.97	Increasing returns
62	PSON	46.57	79.29	58.73	Increasing returns
63	REL	100	100	100	Constant
64	RMV	100	100	100	Constant
65	RNK	72.36	83.7	86.45	Increasing returns
66	RTN	39.94	81.15	49.22	Increasing returns
67	SAGA	73.67	87.16	84.52	Increasing returns
68	SBRY	32.75	100	32.75	Increasing returns
69	SGC	42.26	89.75	47.09	Increasing returns
70	SKY	83.44	100	83.44	Increasing returns
71	SMWH	56.08	97.46	57.54	Increasing returns
72	SPD	35.58	87.02	40.89	Increasing returns
73	SPO	67.03	73.22	91.55	Decreasing returns
74	SSPG	71.17	93.42	76.18	Increasing returns
75	STVG	100	100	100	Constant
76	TCG	91.54	100	91.54	Increasing returns
77	TNI	93.14	93.6	99.51	Decreasing returns
78	TPT	54.07	72.01	75.09	Increasing returns
79	TRS	96.59	100	96.59	Decreasing returns
80	TSCO	32.77	100	32.77	Increasing returns
81	TUI	48.26	100	48.26	Increasing returns
82	UBM	100	100	100	Constant
83	WIZZ	71.52	89.02	80.34	Increasing returns
84	WMH	85.15	94.7	89.92	Increasing returns
85	WPP	31.9	100	31.90	Increasing returns
86	WTB	33.72	90.71	37.17	Increasing returns
87	ZPG	100	100	100	Constant

Although twenty-four organization achieved 100% technical efficiency scores, their overall efficiency was less than 100% due to scale inefficiency. Twenty organizations obtained an increasing return to scale, namely AO, BOK, CCL, CPG, DC, IHT, INCH, ITV, JD., LCL, LOOK, MORW, NXT, PDG, SBRY, SKY, TCG, TSCO, TUI, and WPP. This reflects that in order to achieve 100% overall efficiency, they have to expand the scale of their operations in order to benefit from higher productivity. On the other hand, four organizations had 100% technical efficiency and overall efficiency less than 100% due to scale inefficiency and obtained a decreasing return to scale, namely GYM, HSW, OTB, and TRS. Hence, these organizations should downsize their operations in order to achieve 100% overall efficiency. The remaining organizations are inefficient either in technical efficiency or scale efficiency.

5.7.1.4 Potential improvements

Once the inefficient organizations had been determined, in order to assist managers to determine aspects of deficiency and take decisions to deal with this situation, DEA provides the potential improvements that the inefficient organizations can follow to be efficient. Since the most efficient organizations have operated in the same environment, the inefficient organizations could enhance their performance by choosing the same policies and managerial structures as their respective peer (reference) organizations. For the efficient organizations, there are no changes to the actual values of their variables. Table 5.29 shows the potential improvements for each inefficient organization. Additionally, the table represents the reference set for each unit.

For clarity in discussing the results, the researcher will discuss the potential improvements for the organizations operating below the average and will consider only two organizations operating above the average with the lowest efficiency scores within this category. The potential improvements for the remaining organizations will be included in Appendix B, Table B.2.

Table 5.29: Potential improvements in consumer services industry in 2016

Category	Variable	MCLS (Efficiency: 90.98%)	WTB (Efficiency: 90.71%)	MOSB (Efficiency: 53.22%)	BMY (Efficiency: 51.72%)
Input	NE	0%	0%	0%	0%
	TOE	0%	0%	0%	0%
	TA	0%	0%	0%	0%
	TC	0%	0%	0%	0%
Financial	OI	189%	154%	179%	119%
	NI	395%	148%	139%	200%

Customer	NS	163%	296%	474%	141%
	RMS	104%	137%	188%	122%
Internal process	TAT	10%	10%	28%	13%
	CSO	10%	19%	28%	10%
Learning and growth	TIA	10%	15%	424%	13%
	PPEM	10%	10%	88%	19%
	Reference set	NXT PDG MOTR RMV CPG	NXT REL IHT	MOTR ITV RMV GOCO FOUR	MOTR RMV AUTO HSW

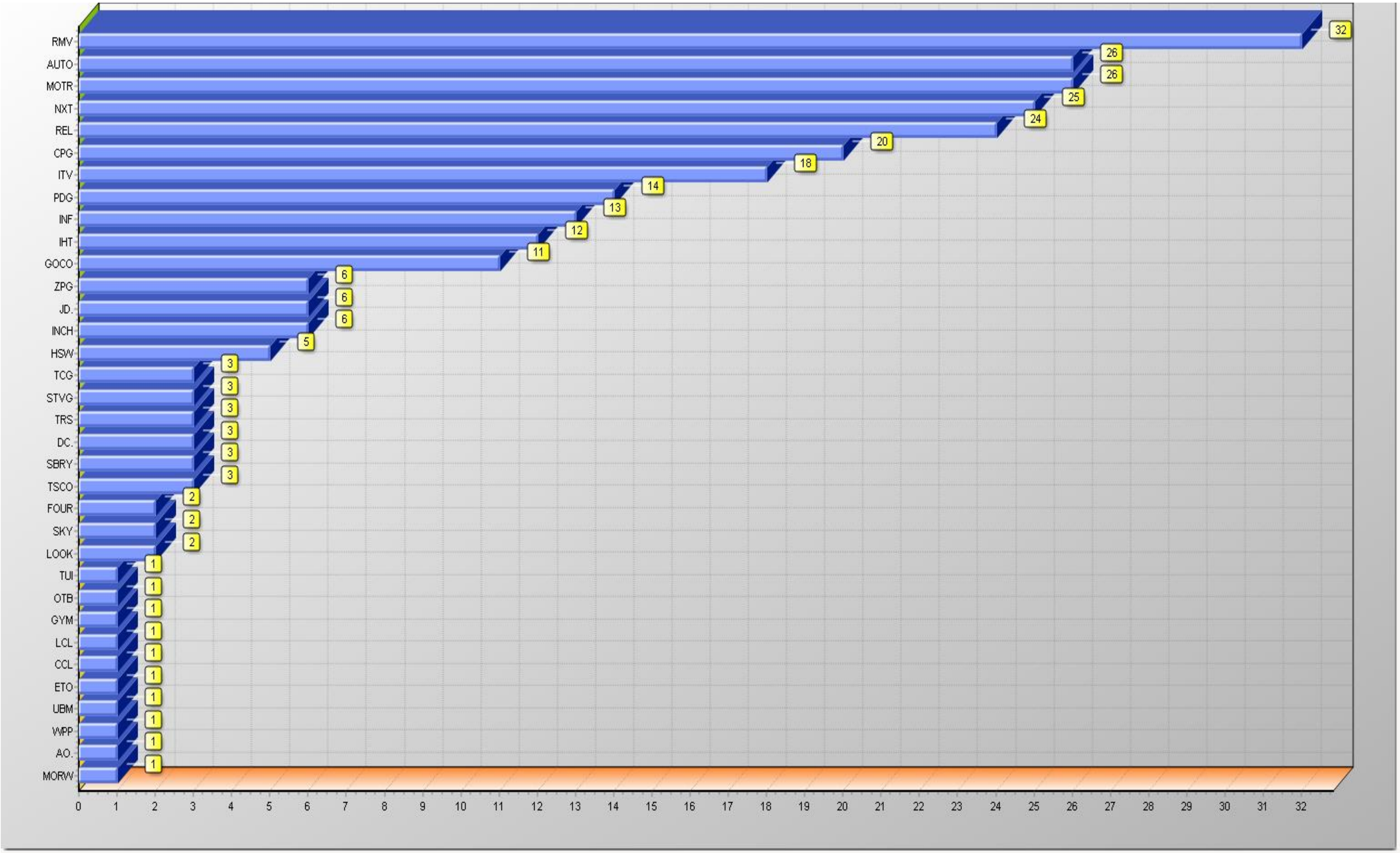
Table 5.29 shows that the consumer services industry is similar to the consumer goods industry in that the customer perspective measures (net sales and relative market share) of the BSC play a dominant role in the improvements suggested by the DEA. On the other hand, the consumer services industry is similar to all other previous industries (technology, oil and gas, health care, basic materials, and consumer goods) in that the financial perspective indicators (net income and operating income) play a significant role in achieving the target efficiency score, whereas, the other perspectives of the BSC (learning and growth, and internal process) have a slight effect on the efficiency scores.

For instance, the MCLS organization is considered to be performing above the average, with an efficiency score of 90.98%, and obtaining increasing returns to scale. The results showed potential improvements in order to achieve 100% efficiency scores: the organization should increase its relative market share, net sales, operating income and net income by 104%, 163%, 395%, and 189%. For the most inefficient organization, which obtains the lowest efficiency score of 51.72% is BMY: DEA indicates a potential increase the relative market share, net sales, and operating income net income by 122%, 141%, 200%, and 119% respectively.

5.7.1.5 Reference (Peer) Groups

Figure 5.31 presents the reference set frequency in the consumer services industry with a sample of eighty-seven organizations, the global leader that most frequently appears in the reference set and the overall best performer is RMV. As these organization recurred thirty-two times as part of the peer group over the total study analysis. Consequently, according to all types of efficiencies, the performance of this organization is better compared to the other efficient organizations in the sample.

Figure 5.31: Reference Set Frequency for consumer services industry in 2016



There are multiple peers for each inefficient organization: hence, the analysis of "reference contributions" provides further guidance on selecting a peer from the reference set of an inefficient unit for benchmarking purposes. Reference contributions are also known as peer weights or lambda in DEA mathematics. Figure 5.32 shows that the reference set for the MCLS organization consists of five other efficient organizations, namely NXT, PDG, MOTR, RMV, and CPG. Figures 5.33 to 5.35 show the reference sets for organizations WTB, MOSB, and BMY.

Figure 5.32: MCLS reference contribution

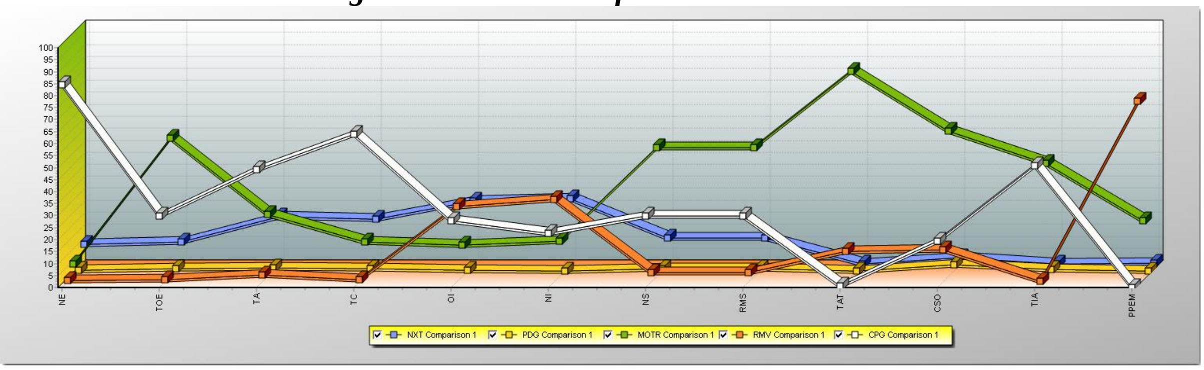


Figure 5.33: WTB reference contribution

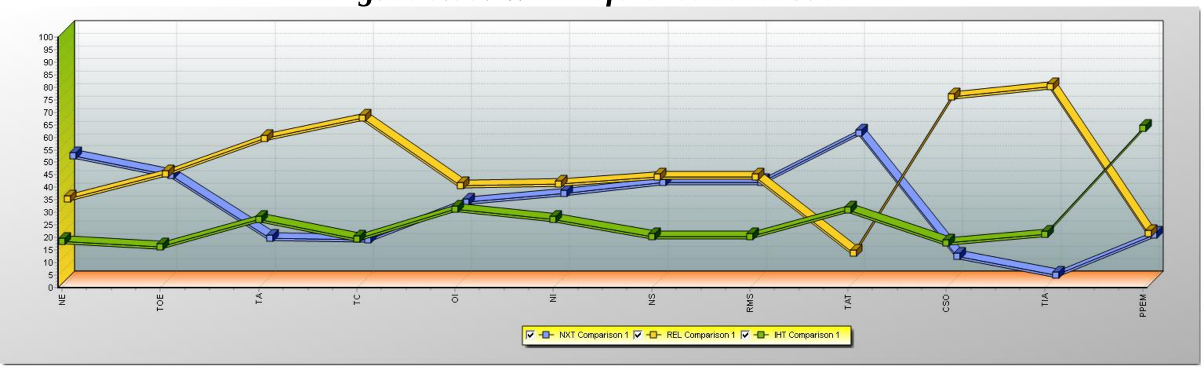


Figure 5.34: MOSB reference contribution

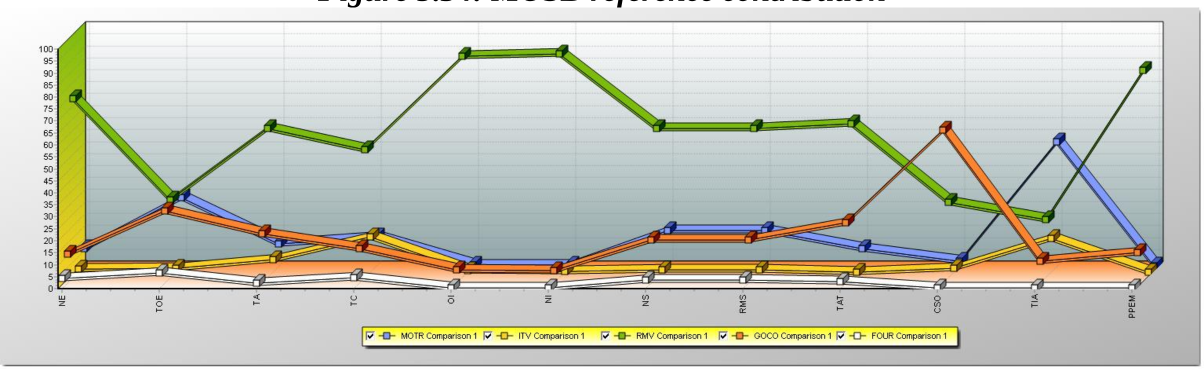
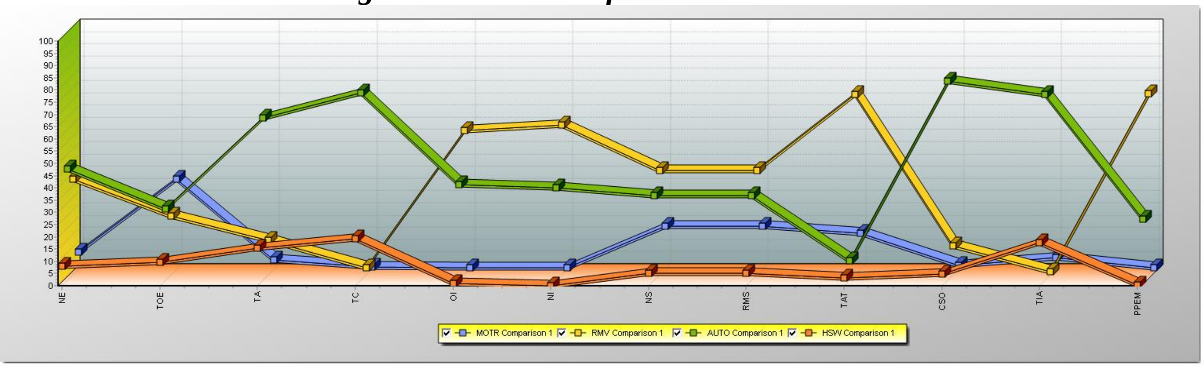


Figure 5.35: BMY reference contribution



<u>5.7.2 Malmquist Productivity Index Results</u>

This section determines the efficiency scores for the eighty-seven consumer services industry organizations for five different years (2016, 2015, 2014, 2013 and 2012), in terms of their ability to maximize their outputs using the same level of inputs by applying the combined DEA-BCC model. Hence, the results that are produced from this analysis show how the efficiency scores of the organizations changed during the period under consideration, and how different organizations operate relative to others.

Generally speaking, Table 5.30 shows that consumer services industry is considered as an unstable industry. It can be clearly seen that there are many fluctuations in the efficiency scores of every single organization within the whole period. Nearly half of the organizations are considered stable in their status and maintaining their efficiency condition, either efficient or inefficient. The other half are not stable, with fluctuating efficiency scores.

The average efficiency score indicates that thirty-two out of the eighty-seven organizations are efficient, with efficiency scores of 100%, and that these organizations maintain their 100% efficiency score within the whole of the period examined. The year 2013 showed the best efficiency scores, with fifty-five organizations achieving 100% efficiency scores, followed by the year 2012 and year 2014 with forty-nine and forty organizations respectively achieving 100% efficiency scores. This reflects that the consumer services industry is getting worse.

Table 5.30: Efficiency scores in consumer services industry from 2012 to 2016

DMU	Efficiency Scores					Average
	2016	2015	2014	2013	2012	
AO.	94%	89%	100%	100%	100%	97%
ASCL	84%	91%	100%	100%	89%	93%
AUTO	100%	100%	100%	100%	100%	100%
BME	94%	91%	100%	100%	100%	97%
BMY	52%	49%	52%	78%	80%	62%
BOK	100%	100%	100%	100%	100%	100%
BOWL	79%	68%	64%	69%	75%	71%
BRWN	78%	78%	80%	88%	89%	82%
CARD	87%	80%	83%	92%	91%	87%
CCL	100%	100%	100%	100%	100%	100%
CINE	79%	79%	81%	84%	85%	82%
CPG	100%	100%	100%	100%	100%	100%
CPR	74%	80%	76%	100%	93%	85%
DC.	100%	99%	84%	100%	100%	97%
DEB	87%	87%	86%	92%	95%	89%
DFS	92%	87%	91%	100%	100%	94%
DNLM	91%	92%	92%	100%	100%	95%
DOM	88%	95%	99%	100%	100%	97%
DTY	73%	81%	81%	79%	83%	79%
ERM	87%	88%	97%	100%	100%	94%
ETO	100%	84%	89%	85%	91%	90%
EZJ	96%	100%	100%	100%	100%	99%
FDL	68%	72%	74%	83%	86%	77%
FGP	86%	88%	90%	94%	94%	91%
FOUR	100%	100%	100%	100%	100%	100%
GKN	85%	83%	89%	89%	90%	87%
GOCO	100%	100%	100%	100%	100%	100%
GOG	94%	98%	95%	96%	94%	95%
GREG	85%	86%	86%	94%	95%	89%
GYM	100%	100%	100%	100%	100%	100%
HFD	88%	88%	87%	94%	95%	90%
HNT	77%	71%	77%	96%	96%	83%
HSW	100%	100%	100%	100%	100%	100%
IHT	100%	100%	100%	100%	100%	100%
INCH	100%	100%	100%	100%	100%	100%
INF	100%	100%	100%	100%	100%	100%
ITE	81%	66%	65%	100%	100%	82%
ITV	100%	100%	100%	100%	100%	100%
JD.	96%	97%	97%	100%	98%	98%
JDW	80%	81%	82%	84%	86%	83%
JE.	91%	90%	91%	100%	100%	94%
KGF	97%	97%	100%	100%	100%	99%
LCL	100%	85%	89%	100%	100%	95%
LOOK	100%	100%	100%	100%	100%	100%
MAB	82%	85%	86%	87%	87%	85%
MARS	76%	80%	83%	82%	84%	81%
MCLS	89%	87%	89%	100%	98%	93%
MERL	85%	88%	95%	95%	96%	92%

MKS	98%	98%	96%	96%	96%	97%
MLC	72%	77%	84%	100%	82%	83%
MONY	98%	100%	99%	100%	100%	99%
MORW	100%	100%	100%	100%	100%	100%
MOSB	53%	52%	52%	76%	78%	62%
MOTR	100%	100%	100%	100%	100%	100%
MTC	82%	87%	96%	100%	100%	93%
NEX	81%	83%	86%	88%	87%	85%
NXT	100%	100%	100%	100%	100%	100%
OCDO	82%	82%	81%	84%	85%	83%
OTB	100%	100%	100%	100%	100%	100%
PDG	100%	100%	100%	100%	100%	100%
PETS	92%	85%	88%	97%	93%	91%
PSON	79%	82%	100%	91%	90%	88%
REL	100%	100%	100%	100%	100%	100%
RMV	100%	100%	100%	100%	100%	100%
RNK	83%	86%	82%	100%	95%	89%
RTN	80%	81%	81%	96%	93%	86%
SAGA	87%	96%	88%	89%	91%	90%
SBRY	100%	100%	100%	100%	100%	100%
SGC	88%	91%	91%	91%	86%	89%

SKY	100%	100%	100%	100%	100%	100%
SMWH	93%	97%	100%	100%	100%	98%
SPD	87%	91%	91%	93%	93%	91%
SPO	73%	80%	74%	99%	99%	85%
SSPG	91%	90%	91%	93%	92%	91%
STVG	100%	100%	100%	100%	100%	100%
TCG	100%	100%	100%	100%	100%	100%
TNI	94%	83%	84%	87%	95%	88%
TPT	70%	70%	71%	85%	89%	77%
TRS	100%	100%	100%	100%	100%	100%
TSCO	100%	100%	100%	100%	100%	100%
TUI	100%	100%	100%	100%	100%	100%
UBM	100%	100%	100%	100%	100%	100%
WIZZ	89%	93%	98%	100%	100%	96%
WMH	94%	93%	100%	100%	100%	97%
WPP	100%	100%	100%	100%	100%	100%
WTB	91%	91%	90%	91%	91%	91%
ZPG	100%	100%	100%	100%	100%	100%
No. of efficient DMUs	35	34	40	55	49	32

5.8 Industrials Industry

The industrial industry includes one hundred organizations in seven sectors, namely Construction and Materials, General Industrials, Aerospace and Defence, Electronic and Electrical Equipment, Industrial Engineering, Industrial Transportation, and Support Services. The list of organizations names, codes, and sectors which are adopted in the analysis of the industrials industry are included in Appendix A, Table A.7.

5.8.1 BCC Model – Technical Efficiency

In order to evaluate the pure technical efficiency of the industrial industry, the BCC model will be applied. Variable returns to scale will also be examined.

5.8.1.1 Model Validation

The analysis will start with the model validation in order to check the validity of the applied BCC model. Each model operates with the target variables substituted in place of the actual variables. Table 5.31 represents the results of the BCC validation model. In each of the one hundred model runs, the substituted variables return an efficiency score of 100% as expected. These results validate both the model and the target variables.

5.8.1.2 Efficiency scores

Based on the BCC model in Table 5.31, Figure 5.36 shows a graph presenting the technical efficiency scores and rankings for the 100 organizations of the industrial industry. The graph shows that forty-six of the 100 organizations are efficient and obtain 100% efficiency scores. These organizations are shaded in green. A further thirty-five organizations are operating above average, with scores of 90% or more: these organizations are shaded in yellow. Nineteen organizations are operating below average, with efficiency scores less than 90%, and are shaded in red.

Figure 5.36: Distribution of efficiency scores for industrial industry in 2016

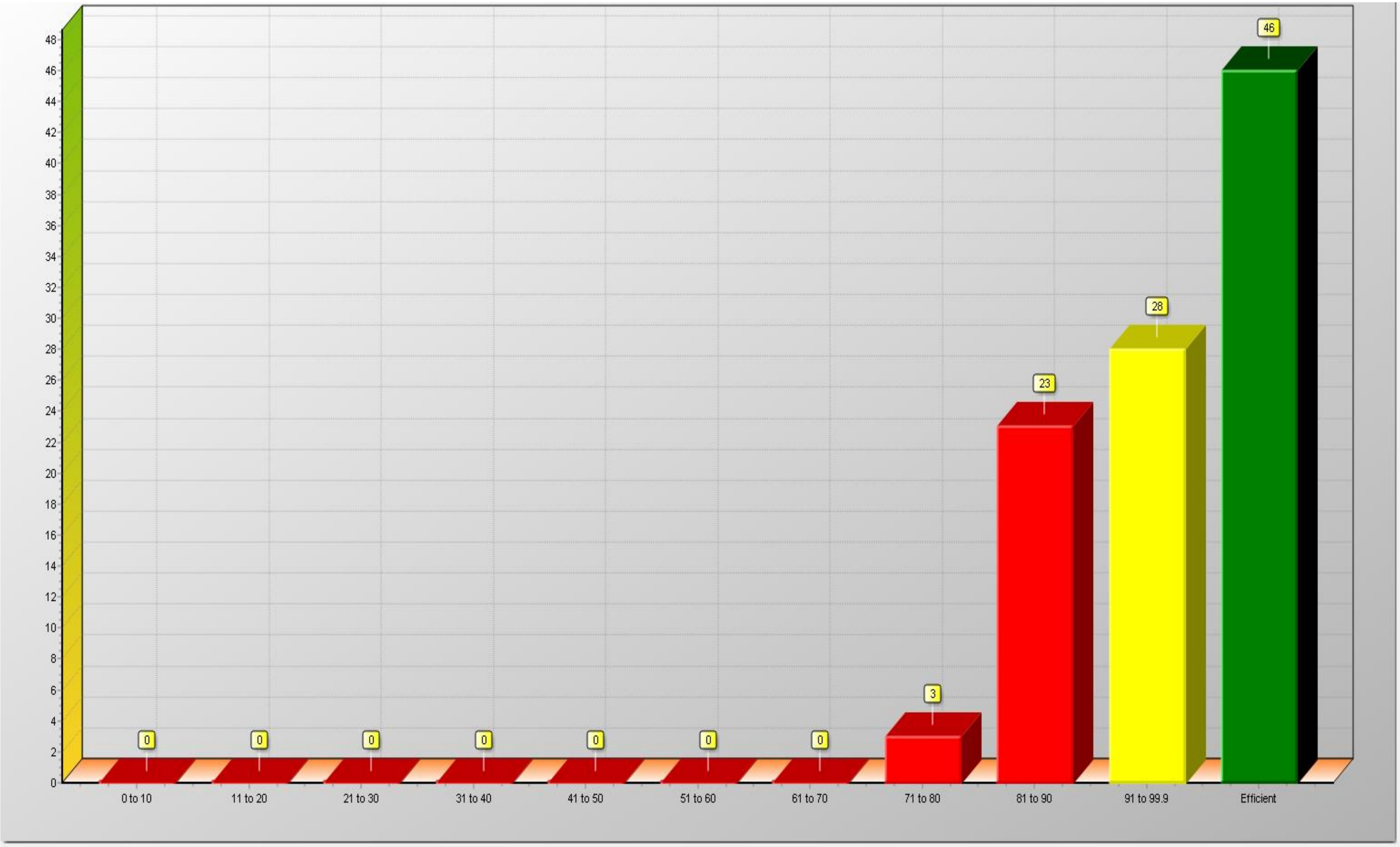


Table 5.31: BCC Model Validation Results for industrial industry in 2016

NO.	DMU	BCC model actual Result %	Target NE	Target TOE	Target TA	Target TC	Target OI	Target NI	Target NS	Target RMS	Target TAT	Target CSO	Target TIA	Target PPEM	VRS validation Result %
1	SXS	100	2173	169100	112700	77100	13100	-2800	182200	0	1.62	32504	15400	-1.29	100
2	RMG	100	6848	1387615	3577564	2811575	210864	-73561	1598479	0	0.45	1031295	2021174	-10.74	100
3	CNCT	100	3566	384100	411000	-145600	70400	16400	454500	0	1.11	101359	13400	4.6	100
4	COB	100	10898	2725400	2750700	1693400	-781500	-795200	1943900	0	0.71	1965310	1165900	-72.97	100
5	PLP	100	1337	134462	262468	204780	20002	15607	154464	0	0.59	200000	173589	11.67	100
6	AA.	100	31628	4262000	4269300	1484100	952200	124200	5214200	0.01	1.22	430300	1669300	3.93	100
7	BA.	100	83100	16239000	21725000	7889000	1551000	913000	17790000	0.02	0.82	3175551	11264000	10.99	100
8	BBY	100	2683	353028	705086	495013	81659	90363	434687	0	0.62	406317	123286	33.68	100
9	BNZL	100	5095	4201900	6558100	2487900	338900	131500	4540800	0	0.69	2000000	2150400	25.81	100
10	BODY	100	3719	496638	750114	485389	93440	67173	590078	0	0.79	870051	360426	18.06	100
11	BOOT	100	1580	235100	287700	207000	59400	27500	294500	0	1.02	200442	13700	17.41	100
12	CLG	100	17500	1101000	306200	-129300	46400	61100	1147400	0	3.75	123747	90000	3.49	100
13	ESNT	100	9214	4047400	1095200	482800	184000	124500	4231400	0	3.86	1432933	242000	13.51	100
14	GDWN	100	2187	151100	158900	46600	14100	10400	165200	0	1.04	223065	33000	4.76	100
15	GFS	100	32150	1919200	2540800	1621100	248900	167800	2168100	0	0.85	1829333	999600	5.22	100
16	HWDN	100	7862	631000	1773000	958000	342000	6000	973000	0	0.55	608182	1298000	0.76	100
17	IBST	100	441	266025	374554	240474	40781	28238	306806	0	0.82	132080	4909	64.03	100
18	ITRK	100	13106	1696100	4749000	3492600	849600	407600	2545700	0	0.54	503326	640500	31.1	100
19	KIE	100	21829	6844000	4723000	1588000	79000	24000	6923000	0.01	1.47	690000	1162000	1.1	100
20	LUCE	100	2173	189046	246946	190603	51997	39555	241042	0	0.98	19242	94499	18.2	100
21	MGGT	100	11210	1778000	5297600	3633500	214400	171200	1992400	0	0.38	775710	3780300	15.27	100
22	MSLH	100	5982	2521600	1093300	292900	40000	36800	2561600	0	2.34	44708	217000	6.15	100
23	MTO	100	2116	596239	1591352	1353907	147761	105634	744000	0	0.47	489795	1231459	49.92	100
24	NTG	100	714	161303	234582	87863	51253	-2111	212556	0	0.91	68087	16106	-2.96	100
25	PAGE	100	350	46027	218467	190882	17942	12948	63969	0	0.29	135188	82681	36.99	100

26	PAYS	100	1598	327200	342500	237800	55400	38300	382600	0	1.12	113240	170800	23.97	100
27	QQ.	100	6207	658300	767500	324800	97400	106100	755700	0	0.98	586681	81400	17.09	100
28	RNO	100	1302	228960	223234	148615	10400	8600	239360	0	1.07	297504	59192	6.61	100
29	RPS	100	3657	321800	369800	285300	11600	-52700	333400	0	0.9	523300	1600	-14.41	100
30	SDY	100	2590	922093	228950	75670	37768	27242	959861	0	4.19	129059	11597	10.52	100
31	SHI	100	4335	336900	843200	705100	45700	30500	382600	0	0.45	300000	670100	7.04	100
32	SMDS	100	19090	967596	1276920	390578	116329	44107	1083925	0	0.85	1407612	236650	2.31	100
33	TTG	100	626	77775	158487	140644	18403	14801	96178	0	0.61	77777	33139	23.64	100
34	VP.	100	51381	8175000	8406000	3004000	647000	242000	8822000	0.01	1.05	1714474	1908000	4.71	100
35	WIN	100	16935	2306046	5044608	3832176	723844	501430	3029891	0	0.6	959837	3917784	29.61	100
36	AHT	100	16285	6985600	4504800	2596100	443500	265900	7429100	0.01	1.65	335607	1929200	16.33	100
37	AVON	100	864	124748	122580	42001	18136	18279	142884	0	1.17	31023	47357	21.16	100
38	BAB	100	38175	13574000	8024000	4103000	856000	659000	14430000	0.02	1.8	252377	1104000	17.26	100
39	CKN	100	964	129118	562573	462561	-2388	8794	126730	0	0.23	344322	112296	9.12	100
40	CMS	100	5968	1839100	410200	99800	67400	33400	1906500	0	4.65	246700	164800	5.6	100
41	CPI	100	8852	1070100	721800	397000	237200	185600	1307300	0	1.81	628535	7300	20.97	100
42	DLAR	100	4939	274900	393600	16500	43400	18700	318300	0	0.81	325354	242100	3.79	100
43	RTRK	100	4998	582800	827500	582600	174600	121300	757400	0	0.92	73238	169700	24.27	100
44	STOB	100	3433	276057	117281	35708	14268	10336	290325	0	2.48	100005	24898	3.01	100
45	XAR	100	2086	116523	105442	50483	17230	9657	133753	0	1.27	160800	12898	4.63	100
46	RR.	100	49900	13776000	24662000	5049000	1179000	-403200	14955000	0.02	0.61	1838797	5080000	-80.8	100
47	FERG	99.47	13465	2171300	2098000	1242007.9	409286	256349.62	2580586.2	0	1.56	640264.17	789054.18	20.89	100
48	CTR	99.2	2164	329687.93	321827	176966	35156.15	24720.97	364844.08	0	1.13	211060.62	189414.85	15.24	100
49	FAN	99.02	4190	1518078.3	468105.05	129700	71183.23	44695.68	1589261.5	0	3.54	371033.81	66551.65	9.93	100
50	WPG	99.01	24983	7170000	5326000	2133854.5	495922.2	316651.4	7665922.2	0.01	3.09	1567114.5	2163935.1	13.43	100
51	GFTU	98.68	5537	1095173	439851	199368.38	116932.96	86808.33	1212106	0	3.19	340738.56	38389.14	13.16	100
52	TRI	98.31	38135	8509000	7591000	3032304.6	900993.87	387223.65	9409993.9	0.01	1.74	1017186.7	2908468.6	9.97	100
53	RPC	97.55	37818	7329000	8674000	3840325.9	1035068.4	455159.5	8364068.4	0.01	1	1015018.5	3323645.8	15.7	100
54	RWI	96.51	3229	972293	320224	101943	62333.74	38936.92	1034626.7	0	3.45	220118.42	23569.9	9.56	100

55	MER	96.23	8025	1943600	561100	193000	115585.61	78776.93	2059185.6	0	3.9	482293.31	138605.83	9.56	100
56	SFR	96.14	1185	147555	155868	75219.69	20288.82	11900.98	167843.82	0	1.12	121431.68	39793.87	12.11	100
57	HSV	96.12	8608	2045400	1851680.3	935600	278140.56	144402.01	2323540.6	0	1.83	959292.28	767889.91	16.78	100
58	RWA	94.65	3250	489922	666063	494713.12	74574.61	51270.76	564496.68	0	1.02	267669.78	481255.24	11.59	100
59	RENT	94.4	24656	5846400	4927000	2596015	739441.66	309120.15	6585841.8	0.01	1.34	491359.96	2001112	14.64	100
60	IWG	94.27	9019	2119700	1232400	576034.71	247873.27	80301.67	2367573.3	0	2.6	779853.83	564763.66	8.88	100
61	RSHW	94.23	5416	658239	1220492	841925.99	198996	115501.06	857235.16	0	0.95	401878.23	823496.72	20.61	100
62	MGNS	93.75	2852	374300	592100	379644.93	91748.97	47148.93	466049.02	0	1.04	213343.57	396392.35	16.05	100
63	HRG	93.67	4319.	908940	478717	203831.14	94668.92	37824.17	1003608.9	0	2.45	234010.92	234461.88	12.95	100
64	FORT	93.46	2250	351573	331257	209757.75	73131.93	39964.35	424704.93	0	1.28	213334.72	42899.35	17.76	100
65	TYMN	93.3	3407	357085	526104.57	381385	110845.09	74053.42	467929.32	0	1.01	86015.38	119156.45	19.66	100
66	SNN	92.96	10315	2648500	1476300	747958.94	298720.54	133277.51	2947220.5	0	2.5	999059	462123.49	13.5	100
67	SMIN	92.33	26065	3738000	4020000	1972116.1	665679.68	228722.32	4403679.9	0	1.49	1023481.9	2007069.4	11.26	100
68	DPLM	92.14	11809	2889281	2337609	1363645.3	425527.36	170785.04	3314808.4	0	2.25	996111	774947.43	14.31	100
69	BBA	91.96	1392	261900	559687.47	406700	70959.85	38820.97	332859.89	0	0.72	171761.66	326770.32	27.89	100
70	PAY	91.77	2408	295800	291100	138580.57	66413.82	42861.85	362213.82	0	1.24	148543.71	100578.63	20.12	100
71	TPK	91.68	6090	1276000	2460000	1632727.1	376450.7	185245.77	1652450.7	0	0.89	464094.96	390442.18	46.11	100
72	XPP	91.5	18791	2454000	4227000	2597292.3	768990.29	286758.72	3222990.6	0	0.76	616844.09	1903848.6	18.02	100
73	MRO	91.29	19393	4001000	2452507.1	892100	503579.87	123192.46	4504579.9	0	2.73	937935.14	870398.36	8.87	100
74	FENR	91.1	1151	110094	158235	99629.94	25508.26	9701.01	135602.25	0	0.9	102777.43	23381.72	11.46	100
75	WEIR	90.88	10901	1446300	1626200	870967.51	368085.08	143918.48	1814385.1	0	1.44	644705.8	573473.32	14.27	100
76	ULE	90.56	4466	685120	1050008	653180.57	182594.88	64336.2	867714.95	0	1.01	357044.48	650683.52	14.41	100
77	HSS	90.34	15201	3077600	1832600	713929.14	408369.46	136569.13	3485969.5	0	2.56	833511.91	568948.12	12.51	100
78	IMI	90.33	3930	472100	517400	262525.95	125786.45	58141.03	597886.45	0	1.25	275982.94	184314.19	13.04	100
79	COST	90.28	2964	409554	732361	532985.21	97362.65	70243.02	506916.76	0	0.92	215851.91	531698.58	17.32	100
80	IRV	90.19	2921	525948	863263	566135.17	159608.83	72861.3	685556.83	0	0.97	211696.8	89927.39	23.34	100
81	BRSN	90.1	30377	4508800	5955400	2823354.7	927484.67	317342.41	5436285	0.01	0.96	815837.13	3056946.1	13.74	100
82	HAS	89.68	4425	546300	925866.77	514400	159774.64	68689.52	706074.72	0	0.96	343327.16	510376.5	15.52	100
83	STHR	89.29	1751	179153	269795	177299.25	54637.58	25780.79	233789.94	0	0.9	51884.51	94905.71	13.6	100

84	CLLN	89.28	6024	1251000	893000	476274.83	195095.92	86783.2	1446095.9	0	1.64	573754.92	270267.95	8.35	100
85	EXPN	89.19	21229	3927500	5553100	3516774.5	734773.7	434314.04	4662274.4	0	0.86	881921.15	3617792.2	23.59	100
86	HLMA	88.55	7832	882100	1033200	368700	235021.58	75372.32	1117121.6	0	1.22	404474.68	390433.08	9.05	100
87	MGAM	87.76	8900	1192200	1718600	918166.07	341379.97	53134.44	1533580	0	1.09	696395.21	1025007.6	5.35	100
88	DIA	86.59	4041	546400	463000	229944.52	111756.4	63175.21	658156.4	0	1.52	262441.01	165376.38	18.06	100
89	SKG	86.19	5053	509900	891900	568660.02	186910.06	77732.66	696809.49	0	1	267019.69	356099.96	15.84	100
90	MNZS	85.86	3500	581700	827500	495600	134353.8	50114.38	716053.8	0	0.93	533595.19	317360.69	8.35	100
91	SNR	84.6	7293	851900	969700	516154.37	232032.49	94580.94	1083932.5	0	1.5	518791.67	448348.52	13.33	100
92	BIFF	84.16	1198	156999	249406.02	113873	44112.11	12524.29	201111.11	0	1.01	80031.44	112694.64	15.61	100
93	RCDO	83.93	6460	886300	930700	505092.1	218823.4	90979.65	1105123.4	0	1.35	510563.28	344703.18	9.26	100
94	AGK	83.57	8987	972100	1649500	1010792.8	356140.9	141245.96	1328240.9	0	1.14	604648.54	605579.2	14.12	100
95	COA	82.89	10826	1280000	1978500	1061953.8	410707.74	95236.37	1690707.7	0	1.02	615322.17	943316.95	8.64	100
96	ECOM	82.08	7908	915900	1409600	795641.57	300539.01	85569.22	1216439	0	1.12	600882.05	708665.57	8.85	100
97	VSVS	82.07	12863	1465300	2723200	1501404.5	535924.57	103308.06	2001224.6	0	0.73	550158.7	1206047.3	7.32	100
98	SPRX	80.83	13600	1688300	3481600	2304125.6	594218.06	237537.81	2282518.4	0	0.67	696453.11	2015158.5	15.16	100
99	HILS	80.4	4530	546400	692200	369486.52	165706.55	63306.77	712106.55	0	1.13	334058.85	221779.21	5.53	100
100	EQN	78.77	3254	329335	484081	258341.69	105371.14	33844.04	434705.97	0	1.08	216085.98	226938.07	9.61	100

The BCC model measures only managerial efficiency. From this perspective the performance of more than half of the industrial organizations is inefficient. As shown in Table 5.32, about 46% of organizations in the analysis are technically efficient. This reflects that the managerial teams have a significant role and a positive impact on the overall efficiency of their organizations. The implication of this is that there are greater efficiencies to be achieved in other areas: i.e. scale efficiencies.

Table 5.32: Efficiency score category for industrial industry at 2016

Efficiency score categories	**Number**	**Percentage**
Efficient (Equal to 100%)	46	46 %
Above average (Less than 100% and ≤ 90%)	35	35 %
Below average (Less than 90%)	19	19 %
Total	100	100%

Additionally, as shown in Table 5.31, thirty-five organizations are performing above the average, with scores ranged between 99.47% and 90.1%. A further nineteen organizations are categorized as performing below the average, with efficiency scores ranging between 89.68% and 78.77%.

5.8.1.3 Return to scale

Table 5.33 shows technical efficiency decomposed into pure technical efficiency and scale efficiency. Technical efficiency scores are obtained from a CRS run, whereas pure technical efficiency scores are generated through a VRS run. The last column identifies the returns to scale prevailing in each DMU at the time of measurement.

The results of Table 5.33 show that the overall efficiency and pure technical efficiency scores for thirty-five of the 100 organizations are the same, at 100%, which in return proves that they are operating efficiently and are at their optimal size: in other words, they have no scale effects.

Table 5.33: Returns to Scale for industrial industry in 2016

No	DMU	**Technical Efficiency %**	**Pure Technical Efficiency %**	**Scale Efficiency %**	**Returns to Scale**
1	AA.	100	100	100	Constant
2	AGK	83.23	83.57	99.59	Increasing returns
3	AHT	98.99	100	98.99	Increasing returns
4	AVON	100	100	100	Constant
5	BA.	100	100	100	Constant
6	BAB	96.97	100	96.97	Increasing returns
7	BBA	91.72	91.96	99.74	Decreasing returns
8	BBY	100	100	100	Constant
9	BIFF	81.67	84.16	97.04	Decreasing returns
10	BNZL	100	100	100	Constant
11	BODY	100	100	100	Constant
12	BOOT	100	100	100	Constant
13	BRSN	84.19	90.1	93.44	Increasing returns
14	CKN	98.59	100	98.59	Increasing returns
15	CLG	100	100	100	Constant
16	CLLN	88.95	89.28	99.63	Increasing returns
17	CMS	100	100	100	Constant
18	CNCT	100	100	100	Constant
19	COA	81.82	82.89	98.71	Increasing returns
20	COB	83.58	100	83.58	Increasing returns
21	COST	88.31	90.28	97.82	Decreasing returns
22	CPI	100	100	100	Constant
23	CTR	98.65	99.2	99.45	Decreasing returns
24	DIA	86.16	86.59	99.50	Decreasing returns
25	DLAR	100	100	100	Constant
26	DPLM	91.09	92.14	98.86	Increasing returns
27	ECOM	81.55	82.08	99.35	Increasing returns
28	EQN	78.33	78.77	99.44	Decreasing returns
29	ESNT	100	100	100	Constant
30	EXPN	84.45	89.19	94.69	Increasing returns
31	FAN	98.35	99.02	99.32	Decreasing returns
32	FENR	90.3	91.1	99.12	Decreasing returns
33	FERG	95.17	99.47	95.68	Increasing returns
34	FORT	93.41	93.46	99.95	Increasing returns
35	GDWN	100	100	100	Increasing returns
36	GFS	89.32	100	89.32	Increasing returns
37	GFTU	98.52	98.68	99.84	Decreasing returns
38	HAS	89.6	89.68	99.91	Increasing returns
39	HILS	80.22	80.4	99.78	Increasing returns
40	HLMA	87.99	88.55	99.37	Increasing returns
41	HRG	93.23	93.67	99.53	Decreasing returns
42	HSS	89.04	90.34	98.56	Increasing returns
43	HSV	95.68	96.12	99.54	Increasing returns
44	HWDN	100	100	100	Constant
45	IBST	100	100	100	Constant
46	IMI	90.12	90.33	99.77	Decreasing returns
47	IRV	89.9	90.19	99.68	Increasing returns
48	ITRK	100	100	100	Constant

49	IWG	93.36	94.27	99.03	Increasing returns
50	KIE	91.7	100	91.70	Increasing returns
51	LUCE	100	100	100	Constant
52	MER	95.87	96.23	99.63	Increasing returns
53	MGAM	87.37	87.76	99.56	Increasing returns
54	MGGT	100	100	100	Constant
55	MGNS	93.56	93.75	99.80	Decreasing returns
56	MNZS	83.87	85.86	97.68	Increasing returns
57	MRO	90.59	91.29	99.23	Increasing returns
58	MSLH	100	100	100	Constant
59	MTO	100	100	100	Constant
60	NTG	100	100	100	Constant
61	PAGE	100	100	100	Constant
62	PAY	91.63	91.77	99.85	Decreasing returns
63	PAYS	100	100	100	Constant
64	PLP	100	100	100	Constant
65	QQ.	100	100	100	Constant
66	RCDO	83.67	83.93	99.69	Increasing returns
67	RENT	91.22	94.4	96.63	Increasing returns
68	RMG	88.23	100	88.23	Increasing returns
69	RNO	100	100	100	Constant
70	RPC	88.5	97.55	90.72	Increasing returns
71	RPS	100	100	100	Constant
72	RR.	95.82	100	95.82	Increasing returns
73	RSHW	94.19	94.23	99.96	Decreasing returns
74	RTRK	100	100	100	Constant
75	RWA	93.26	94.65	98.53	Decreasing returns
76	RWI	96.5	96.51	99.99	Decreasing returns
77	SDY	100	100	100	Constant
78	SFR	95.56	96.14	99.40	Decreasing returns
79	SHI	100	100	100	Constant
80	SKG	86.12	86.19	99.92	Decreasing returns
81	SMDS	99.03	100	99.03	Increasing returns
82	SMIN	86.6	92.33	93.79	Increasing returns
83	SNN	92.51	92.96	99.52	Increasing returns
84	SNR	84.48	84.6	99.86	Decreasing returns
85	SPRX	78.88	80.83	97.59	Increasing returns
86	STHR	89.11	89.29	99.80	Decreasing returns
87	STOB	100	100	100	Constant
88	SXS	99.92	100	99.92	Decreasing returns
89	TPK	89.02	91.68	97.10	Increasing returns
90	TRI	86.68	98.31	88.17	Increasing returns
91	TTG	100	100	100	Constant
92	TYMN	93.14	93.3	99.83	Decreasing returns
93	ULE	90.48	90.56	99.91	Increasing returns
94	VP.	100	100	100	Constant
95	VSVS	80.16	82.07	97.67	Increasing returns
96	WEIR	89.98	90.88	99.01	Increasing returns
97	WIN	100	100	100	Constant
98	WPG	90.15	99.01	91.05	Increasing returns
99	XAR	100	100	100	Constant
100	XPP	88.36	91.5	96.57	Increasing returns

Although eleven organizations achieved 100% technical efficiency scores, their overall efficiency is less than 100% due to scale inefficiency. Ten organizations obtained an increasing return to scale, namely AHT, BAB, CKN, COB, GDWN, GFS, KIE, RMG, RR, and SMDS. This reflects that in order to achieve 100% overall efficiency scores, they have to expand the scale of their operations in order to benefit from higher productivity. On the other hand, only one organization (SXS) had 100% technical efficiency score and overall efficiency of less than 100% due to scale inefficiency and obtained a decreasing return to scale. Hence, it is required to downsize its operations in order to achieve 100% overall efficiency. The remaining organizations are inefficient either in technical efficiency or scale efficiency.

5.8.1.4 Potential improvements

Once the inefficient organizations had been determined, to assist managers to determine aspects of deficiency and take decisions to deal with this situation, DEA provides the potential improvements that the inefficient organizations can follow to be efficient. Since the most efficient organizations have operated in the same environment, inefficient organizations could enhance their performances by choosing the same policies and managerial structures as their respective peer (reference) organizations. For the efficient organizations, there are no changes to the actual values of their variables. Table 5.34 shows the potential improvements for each inefficient organization. Additionally, the table represents the reference set for each unit.

For clarity in discussing the results, the researcher will discuss the potential improvements for the organizations operating below the average and will consider only two organizations operating above the average, with the lowest efficiency scores within this category. The potential improvements for the rest of the organizations will be included in Appendix B, Table B.3.

Table 5.34: Potential improvements in industrial industry in 2016

Category	**Variable**	**IRV (Efficiency: 90.19%)**	**BRSN (Efficiency: 90. 1%)**	**HILS (Efficiency: 80.4%)**	**EQN (Efficiency: 78.77%)**
Input	NE	0%	0%	0%	0%
	TOE	0%	0%	0%	0%
	TA	0%	0%	0%	0%
	TC	0%	0%	0%	0%
Financial	OI	173%	138%	135%	176%
	NI	119%	160%	141%	296%
Customer	NS	11%	11%	24%	27%
	RMS	11%	11%	24%	27%

Internal process	TAT	36%	17%	37%	12%
	CSO	19%	22%	12%	27%
Learning and growth	TIA	11%	11%	24%	27%
	PPEM	11%	13%	19%	21%
	Reference set	IBST ITRK CPI ESNT NTG	BA. WIN ITRK AA.	ITRK CPI HWDN ESNT	AVON XAR LUCE CPI HWDN NTG

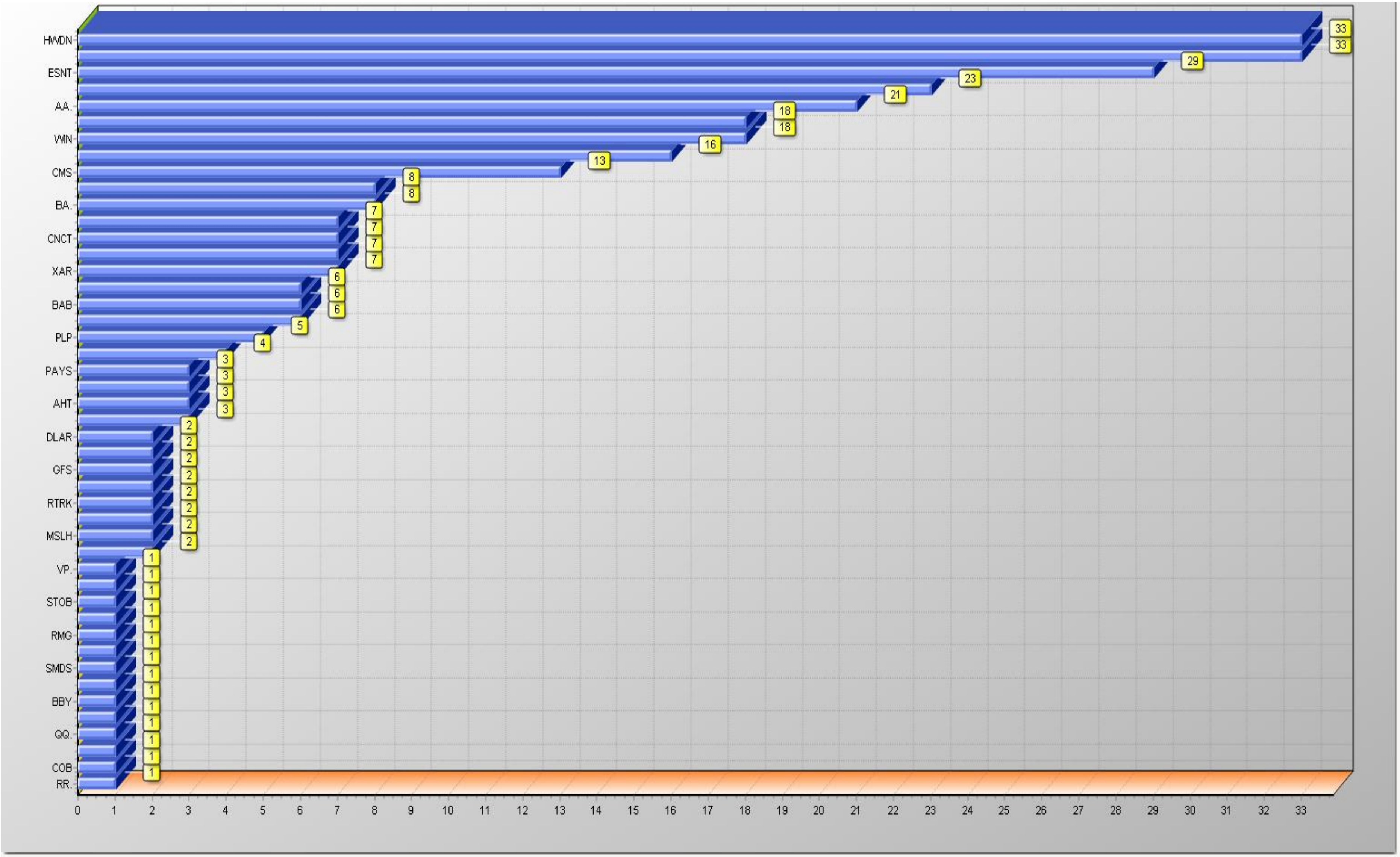
Table 5.34 shows that the industrial industry is similar to all other previous industries (technology, oil and gas, health care, basic materials, consumer goods, and consumer services) in that the financial perspective indicators (net income and operating income) play a significant role in achieving the target efficiency score, whereas the other perspectives of the BSC (customer, internal processes, and learning and growth) have a smaller effect on the efficiency scores.

For instance, IRV is considered to be performing above the average, with an efficiency score of 90.19%, and obtaining increasing returns to scale. The results show potential improvements in order to achieve 100% efficiency scores: the organization should increase its operating income and net income by 173% and 119%. The most inefficient organization, which obtains the lowest efficiency score of 78.77%, is EQN. DEA indicates a potential increase in its operating income and net income by 296% and 176% respectively.

5.8.1.5 Reference (Peer) Groups

Figure 5.37 represents the reference set frequency in the industrial industry with a sample of 100 organizations, the global leader that most frequently appears in the reference set and the overall best performers, namely HWDN and ESNT. These organizations recurred thirty-three times as part of the peer group over the total study analysis. Consequently, according to all types of efficiencies, the performance of these organizations is better compared to the other efficient organizations in the sample.

Figure 5.37: Reference Set Frequency for industrial industry in 2016



As there are multiple peers for each inefficient organization, the analysis of "reference contributions" provides further guidance on selecting a peer from the reference set of an inefficient unit for benchmarking purposes. Figure 5.38 shows that the reference set for the IRV organization consists of five other efficient organizations, namely IBST, ITRK, CPI, ESNT, and NTG. Figures 5.39 to 5.41 show the reference set for the BRSN, HILS, and EQN organizations.

Figure 5.38: IRV reference contribution

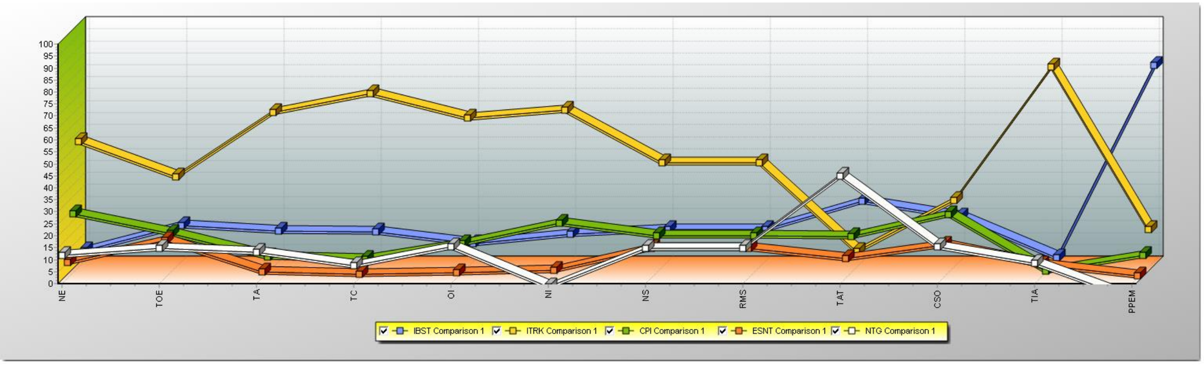


Figure 5.39: BRSN reference contribution

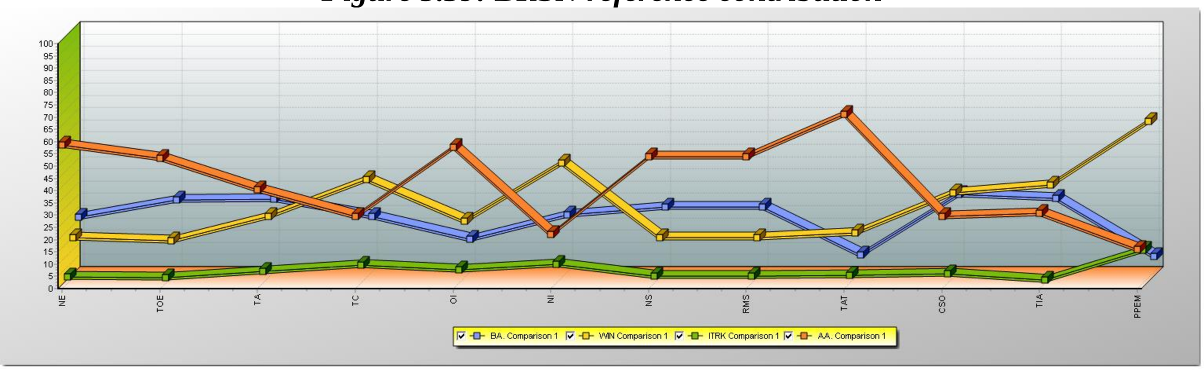


Figure 5.40: HILS reference contribution

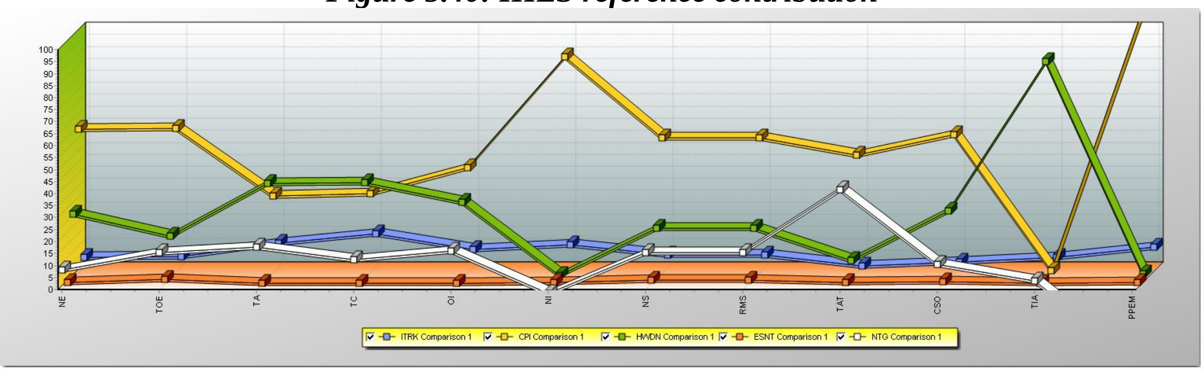
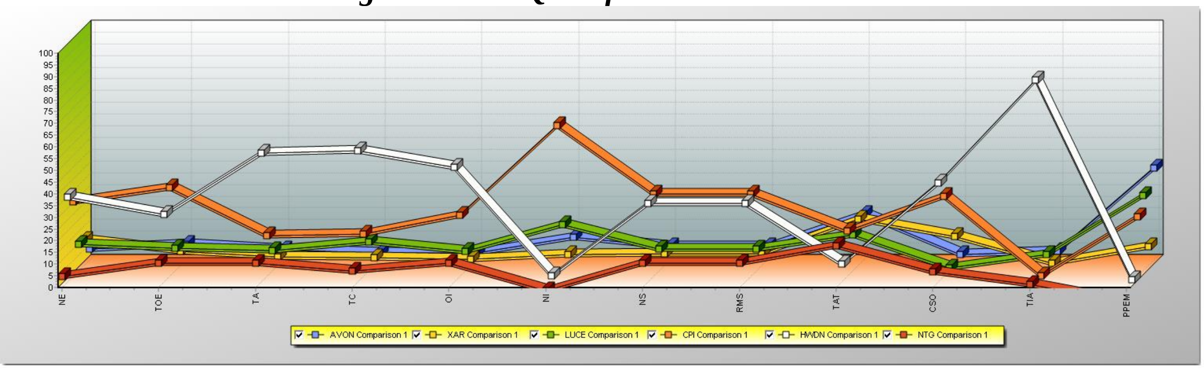


Figure 5.41: EQN reference contribution



5.8.2 Malmquist Productivity Index Results

This section determines the efficiency scores of 100 industrial industry organizations in five different years (2016, 2015, 2014, 2013 and 2012) in terms of their ability to maximize their outputs using the same level of inputs by applying the combined DEA-BCC model. Hence, the results that are produced from this analysis show how the efficiency scores of the organizations changed during the period under consideration, and how different organizations operate relatively to others.

Generally speaking, Table 5.35 shows that the industrial industry is unstable. It can be clearly seen that there are many fluctuations in the efficiency scores of every single organization within the whole period. Only twenty-three organizations are considered stable in their status and maintain their efficiency conditions, either efficient or inefficient. The others are not stable and show significant fluctuations.

The average efficiency score indicates that eighteen out of the 100 organizations are efficient, with efficiency scores of 100%, and that these organizations maintain their 100% efficiency scores across the whole of the period examined. In contrast to the consumer service industry, the year 2016 showed the highest number of organizations (49) with efficiency scores of 100%, followed by the years 2014, 2015, and 2013, with forty-five, forty-four, and forty organizations, respectively. The lowest number of efficient organizations was in 2012, with thirty-six organizations with efficiency scores of 100%. This reflects that the consumer services industry is getting better and operating on the right track.

Table 5.35: Efficiency scores in industrial industry from 2012 to 2016

DMU	Efficiency Scores					Average
	2016	2015	2014	2013	2012	
AA.	100%	100%	100%	100%	100%	100%
AGK	84%	99%	100%	100%	100%	97%
AHT	100%	100%	100%	95%	89%	97%
AVON	100%	100%	100%	100%	95%	99%
BA.	100%	100%	100%	100%	100%	100%
BAB	100%	92%	96%	100%	97%	97%
BBA	92%	96%	86%	88%	88%	90%
BBY	100%	100%	100%	100%	100%	100%
BIFF	84%	83%	80%	81%	80%	82%
BNZL	100%	100%	100%	100%	100%	100%
BODY	100%	85%	86%	89%	89%	90%
BOOT	100%	100%	100%	97%	89%	97%
BRSN	94%	85%	85%	88%	88%	88%
CKN	100%	95%	93%	88%	86%	93%
CLG	100%	100%	100%	100%	96%	99%
CLLN	89%	100%	100%	100%	87%	95%
CMS	100%	96%	96%	95%	94%	96%
CNCT	100%	100%	100%	100%	100%	100%
COA	83%	100%	100%	100%	100%	97%
COB	100%	100%	100%	100%	100%	100%
COST	90%	95%	93%	94%	93%	93%
CPI	100%	100%	94%	92%	92%	96%
CTR	99%	77%	78%	75%	78%	81%
DIA	87%	100%	100%	94%	93%	95%
DLAR	100%	100%	100%	100%	100%	100%
DPLM	92%	100%	100%	100%	97%	98%
ECOM	82%	93%	93%	92%	93%	91%
EQN	79%	97%	100%	100%	100%	95%
ESNT	100%	87%	89%	90%	91%	92%
EXPN	92%	100%	100%	100%	100%	98%
FAN	100%	100%	100%	100%	100%	100%
FENR	91%	84%	83%	88%	91%	87%
FERG	100%	100%	100%	100%	100%	100%
FORT	94%	100%	100%	78%	79%	90%
GDWN	100%	99%	100%	91%	87%	95%
GFS	100%	100%	100%	98%	100%	100%
GFTU	99%	94%	92%	91%	88%	93%
HAS	90%	100%	100%	100%	100%	98%
HILS	80%	90%	88%	86%	87%	86%
HLMA	90%	97%	96%	97%	97%	95%
HRG	94%	100%	100%	100%	100%	99%
HSS	90%	78%	80%	85%	85%	84%
HSV	96%	88%	85%	91%	100%	92%
HWDN	100%	100%	100%	100%	100%	100%
IBST	100%	100%	87%	77%	75%	88%
IMI	90%	91%	100%	100%	100%	96%
IRV	90%	91%	92%	92%	100%	93%
ITRK	100%	97%	95%	100%	97%	98%
IWG	94%	95%	92%	92%	92%	93%
KIE	100%	90%	93%	93%	93%	94%
LUCE	100%	100%	100%	100%	100%	100%
MER	96%	93%	92%	92%	89%	92%
MGAM	88%	88%	88%	89%	90%	89%
MGGT	100%	100%	100%	100%	100%	100%

MGNS	94%	96%	95%	95%	94%	95%
MNZS	86%	96%	96%	97%	97%	94%
MRO	92%	100%	100%	100%	100%	98%
MSLH	100%	91%	88%	80%	78%	87%
MTO	100%	95%	94%	93%	94%	95%
NTG	100%	93%	89%	89%	90%	92%
PAGE	100%	99%	98%	98%	97%	98%
PAY	92%	100%	100%	100%	100%	98%
PAYS	100%	100%	100%	100%	100%	100%
PLP	100%	92%	90%	87%	88%	91%
QQ.	100%	98%	90%	92%	100%	96%
RCDO	84%	88%	95%	92%	87%	89%
RENT	94%	100%	100%	100%	100%	99%
RMG	100%	100%	100%	100%	100%	100%
RNO	100%	100%	100%	86%	86%	94%
RPC	99%	83%	88%	90%	89%	90%
RPS	100%	93%	93%	93%	92%	94%
RR.	100%	100%	100%	100%	100%	100%
RSHW	94%	100%	93%	99%	100%	97%
RTRK	100%	100%	100%	100%	100%	100%
RWA	95%	96%	97%	95%	96%	96%
RWI	97%	84%	81%	79%	83%	85%
SDY	100%	92%	83%	79%	78%	86%
SFR	96%	100%	100%	80%	100%	95%

SHI	100%	93%	94%	94%	93%	95%
SKG	86%	99%	99%	97%	95%	95%
SMDS	100%	93%	93%	92%	90%	94%
SMIN	92%	94%	95%	100%	97%	96%
SNN	93%	100%	100%	100%	100%	99%
SNR	85%	88%	90%	91%	92%	89%
SPRX	81%	97%	96%	97%	96%	93%
STHR	89%	100%	100%	100%	100%	98%
STOB	100%	100%	100%	79%	78%	92%
SXS	100%	90%	89%	100%	96%	95%
TPK	92%	95%	95%	96%	94%	94%
TRI	98%	96%	100%	87%	81%	92%
TTG	100%	87%	88%	86%	85%	89%
TYMN	93%	94%	93%	90%	95%	93%
ULE	91%	88%	86%	94%	95%	91%
VP.	100%	88%	86%	82%	83%	88%
VSVS	82%	84%	85%	89%	87%	85%
WEIR	91%	84%	91%	100%	99%	93%
WIN	100%	100%	97%	100%	100%	99%
WPG	100%	100%	100%	100%	100%	100%
XAR	100%	100%	100%	100%	93%	99%
XPP	92%	100%	100%	99%	98%	98%
No. of efficient DMUs	49	44	45	40	36	18

5.9 Summary

In this new economic and competitive environment, achieving and sustaining competitive advantage necessitates explicit links between strategy and performance measures that move beyond the current collection of financial and non-financial measures by seeking to identify causal links among measures, strategies, and outcomes (Sainaghi, 2013).

Consequently, applying the combined DEA-BSC model provides managers with insights according to the current situation for their organizations (Chang, He, & Wang, 2005). Through a DEA-BSC model, both researchers and professionals can explore the efficiency of decision-making units (DMUs) in the form of individual organizations against an efficiency frontier.

This study applied the DEA-BSC model to evaluate the performance and efficiency levels within seven different industries: industrials, consumer services, consumer goods, basic materials, health care, oil and gas, and technology. Table 5.36 provides a summary of the main research findings.

It can be noticed that the technology and the oil and gas industries are similar to each other in the following respects: they achieve almost identical levels of efficient organizations, organizations operating above the average, and organizations operating below the average. Additionally, in terms of BSC, the financial and learning and growth perspectives, followed by the internal process perspective, play a dominant role in both industries, whereas the customer perspective has only a slight effect on the performance of the organizations in both industries.

From the stability point of view, technology and oil and gas are considered stable industries, as they obtain the same number of efficient organizations within the whole period from 2012 to 2016. Additionally, each organization maintains the same condition within the examined period: either efficient or inefficient. However, in the oil and gas industry, there is a drop in the number of efficient organizations in 2015 and 2016, from seventeen to thirteen efficient organizations.

Additionally, Table 5.36 shows that the healthcare and basic materials industries are similar in that they achieve nearly the same numbers of efficient organizations, organizations operating above the average, and organizations operating below the average. They achieved the highest level of efficient organizations within the seven industries of the study, at 84% and 81%, respectively. Additionally, in terms of BSC perspectives, the financial and internal process perspectives play a dominant role in both industries, whilst the learning and growth and customer perspectives have a slight effect on the performance of the organizations in both industries.

Furthermore, from the stability point of view, healthcare and basic materials are considered stable industries, as they have the same number of efficient organizations within the whole period from 2012 to 2016. Additionally, each organization maintains the same condition within the examined period: either efficient or inefficient. However, in the basic materials industry, there is an increase in the number of efficient organizations in 2016, from sixteen to twenty-one.

The only similarity between the consumer services and consumer goods industries is that in terms of BSC perspectives, financial and customer perspectives play a dominant role in both industries, whilst, the learning and growth and internal process perspectives have a slight effect on the performance of the organizations in both industries. The consumer goods industry is considered as stable within the whole period; however, there is a decrease in the number of efficient organizations in 2015 and 2016. The consumer services industry is considered as unstable, with fluctuations within the examined period. The consumer services industry achieves the highest number of efficient organizations in the year 2013. Furthermore, this industry achieves the lowest level of efficient organizations (40%) of all seven industries in the study.

The only BSC perspective that has a dominant impact on the organizations of the industrial industry is the financial perspective. The other three perspectives – customer, learning and growth, and internal processes – have only a minor impact on the performance of the organizations in both industries. Similar to the consumer services industry, the industrial industry is considered unstable, with fluctuations within the examined period. However, the industrial industry achieves the highest number of efficient organizations in the year 2016. Furthermore, the industrial industry follows the consumer services industry in the ranking of the lowest level of efficient organizations (46%) within the seven industries of the study.

To sum up, it can be clearly seen that the common factor which has the highest effect on the seven industries is the BSC's financial perspective. In 2016, all industries either achieve progress in their performance or maintain the same level, except for the oil and gas and consumer goods industries, which face decreases in the number of efficient organizations.

Table 5.36: Summary of the main research findings

Industry	Technology	Oil & Gas	Health Care	Basic Materials	Consumer Goods	Consumer Services	Industrials
No. of org. analysed	16	17	19	26	42	87	100
Percentage of efficient org.	75%	76%	84%	81%	60%	40%	46%
Percentage of org. operating above the average	6%	6%	5%	4%	36%	18%	35%
Percentage of org. operating below the average	19%	18%	11%	15%	4%	42%	19%
BSC perspectives with highest effect	1. Financial 2. Learning & growth 3. Internal process	1. Financial 2. Learning & growth 3. Internal process	1. Financial 2. Internal process	1. Financial 2. Internal process	1. Financial 2. Customer	1. Financial 2. Customer	1. Financial
BSC perspectives with the lowest effect	1. Customer	1. Customer	1. Learning & growth 2. Customer	1. Learning & growth 2. Customer	1. Learning & growth 2. Internal process	1. Learning & growth 2. Internal process	1. Learning & growth 2. Internal process 3. Customer
Stability of the industry	Stable within the whole period from 2012:2016 (Table 5.4- p.104)	Stable within the whole period, however, there is a decrease happened in the number of efficient organizations at 2015 and 2016 (Table 5.9)	Stable within the whole period from 2012:2016 (Table 5.14)	Stable within the whole period, however, there is an increase happened in the number of efficient organizations at 2016 (Table 5.19)	Stable within the whole period, however, there is a decrease happened in the number of efficient organizations at 2015 and 2016 (Table 5.24)	Not stable, achieve the highest number of efficient organizations at the year 2013 (Table 5.29)	Not stable, achieve the highest number of efficient organizations at the year 2016 (Table 5.34)

Chapter Six: Sensitivity Analysis

6.1 Introduction

Since Charnes, Cooper, and Rhodes (CCR) introduced the primary DEA model in the early 1970s, proponents of DEA have proclaimed that it is the best and most powerful technique for evaluating the relative efficiency of a group of DMUs with multiple inputs and outputs (Bazargan & Vasigh, 2003; Cooper et al., 2007; Hsu et al., 2013; Sağlam, 2017).

The efficiency scores provided by the application of the DEA are classified into three main groups: first, organizations that achieve 100% efficiency scores; second, organizations that achieve above-average efficiency scores (less than 100% but greater than 90%); and third, organizations that achieve below-average efficiency scores (less than 90%). Whereas the organizations operating above and below the average can be ranked based on their scores, efficient organizations cannot be ranked based on their efficiencies because they have the same efficiency score of 100%. Zhu (2001) stated that it is not logical to consider that all the efficient organizations are operating at the same performance level in actual practice. Hence, a question arises as to the process of ranking efficient organizations.

Pioneering studies that provide a response to this question from Banker and Gifford (1988) and Banker, Das, and Datar (1989) have argued that the DEA's super-efficiency technique provides a ranking of all organizations, even the efficient ones. Andersen and Petersen (1993) defined super-efficiency as a ranking methodology to distinguish between the performances of efficient DMUs. Moreover, Chen, Du, and Huo (2013) defined the super-efficiency technique as the ability to rank and identify efficient DMUs. Several studies mentioned the importance of super-efficiency for ranking and identifying efficient DMUs (Andersen & Petersen, 1993; Thrall, 1996), analysing the sensitivity of efficiency classifications (Charnes, Haag, Jaska, & Semple, 1992; Zhu, 2001), and calculating the stability of efficiency (Seiford & Zhu, 1998).

Similar to the previously mentioned studies (Andersen & Petersen, 1993; Charnes et al., 1992; Seiford & Zhu, 1998), the current study will apply the super-efficiency technique for each of the seven industries in order to rank the efficient organizations and to conduct a sensitivity analysis.

6.2 Super-efficiency scores for Technology Industry

As mentioned above, sixteen technological organizations were included in the analysis for this study. The results of the BCC model demonstrate that twelve of these sixteen organizations are considered efficient. After conducting the super-efficiency approach while applying the BCC model and the output maximization approach, the results are consistent with the previous findings. Moreover, super-efficiency provides a ranking of the twelve efficient organizations, as shown in Table 6.1.

Table 6.1: Super-efficiency scores for technology industry organizations

No.	DMU	Score
1	KNOS	1000.00%
2	NANO	1000.00%
3	SERV	1000.00%
4	SCT	476.80%
5	CCC	370.00%
6	MCRO	363.20%
7	SGE	313.10%
8	SPT	195.50%
9	FDM	171.30%
10	SOPH	141.70%
11	FDSA	107.90%
12	NCC	102.50%
13	AVV	92.30%
14	SDL	88.20%
15	LRD	85.50%
16	IMG	78.00%

Table 6.1 shows that the most efficient organizations in the technology industry are KNOS, NANO, and SERV, which achieve efficiency scores of 1000.00%, followed by SCT, with an efficiency score of 476.80%. The lowest efficient organization is NCC, with an efficiency score of 102.50%. Additionally, similar to the BCC model results in section 5.2.1.1, organization AVV is operating above the average and achieves a score of 92.30%. There are three inefficient organizations: SDL (88.20%), LRD (85.50%), and IMG (78.00%).

6.3 Super-efficiency scores for Oil and Gas Industry

For the oil and gas industry, seventeen organizations were included in the analysis. The results of the BCC model demonstrate that thirteen of these organizations are considered efficient. After conducting the super-efficiency approach while applying the BCC model and the output maximization approach, the results are consistent with the previous findings. Moreover, super-efficiency provides a ranking of the thirteen efficient organizations, as shown in Table 6.2.

Table 6.2: Super-efficiency scores for oil and gas industry organizations

No.	DMU	Score
1	EXI	1000.00%
2	CIU	1000.00%
3	CNE	1000.00%
4	RDSA	1000.00%
5	OPHR	1000.00%
6	ENQ	548.60%
7	PMO	493.60%
8	BP.	442.10%
9	PFC	243.50%
10	GMS	156.60%
11	LAM	154.40%
12	WG.	127.80%
13	AMFW	120.90%
14	SIA	92.90%
15	TLW	87.10%
16	HTG	80.90%
17	NOG	58.80%

Table 6.2 shows that there are five extremely efficient organizations in the oil and gas industry, namely EXI, CIU, CNE, RDSA, and OPHR, which achieve efficiency scores of 1000.00%, followed by ENQ, with an efficiency score of 548.60%. The lowest efficient organization is AMFW, with an efficiency score of 120.90%. Additionally, similar to the BCC model results in section 5.3.1.1, organization SIA is operating above the average and achieves a score of 92.90%. There are three inefficient organizations: TLW (87.10%), HTG (80.90%), and NOG (58.80%).

6.4 Super-efficiency scores for Health Care Industry

Nineteen organizations in the health care industry are included in the analysis. The results of the BCC model demonstrate that sixteen of them are considered efficient. After conducting the super-efficiency approach while applying the BCC model and the output maximization approach, the results are consistent with the previous findings. Moreover, the super-efficiency technique provides a ranking of the sixteen efficient organizations, as shown in Table 6.3.

Table 6.3 Super-efficiency scores for Health Care industry organizations

No.	DMU	Score
1	CSRT	1000.00%
2	OXB	1000.00%
3	DPH	1000.00%
4	GHG	1000.00%
5	INDV	1000.00%
6	VEC	1000.00%
7	CMBN	935.10%
8	CIR	613.00%
9	AZN	344.50%
10	SHP	330.50%
11	GSK	312.00%
12	BTG	266.00%
13	SN.	154.00%
14	UDG	131.20%
15	CTEC	111.40%
16	MGP	105.20%
17	HIK	91.80%
18	GNS	82.20%
19	SPI	80.40%

Table 6.3 shows that there are six extremely efficient organizations in the health care industry, namely CSRT, OXB, DPH, GHG, INDV, and VEC, which achieve efficiency scores of 1000.00%, followed by CMBN, with an efficiency score of 935.10%. The lowest efficient organization is MGP, with an efficiency score of 105.20%. Additionally, similar to the BCC model results in section 5.4.1.1, organization HIK is operating above the average and achieves a score of 91.80%, while there are two inefficient organizations: GNS (82.20%), and SPI (80.40%).

6.5 Super-efficiency scores for Basic Materials Industry

For the basic materials industry, twenty-six organizations have been included in the analysis. The results of the BCC model provide that twenty-one of these organizations are considered efficient. After conducting the super-efficiency approach while applying the BCC model and the output maximization approach, the results are consistent with the previous findings. Moreover, the super-efficiency technique provides rankings for the twenty-one efficient organizations, as shown in Table 6.4.

Table 6.4: Super efficiency scores for basic materials industry organizations

No.	DMU	Score
1	SXX	1000.00%
2	TET	1000.00%
3	ZTF	1000.00%
4	JMAT	1000.00%
5	GLEN	611.50%
6	POG	464.90%
7	RIO	377.20%
8	BLT	182.10%
9	GEMD	178.10%
10	ELM	177.40%
11	CRDA	174.80%
12	RRS	167.20%
13	ANTO	145.70%
14	MNDI	145.30%
15	SYNT	144.50%
16	FXPO	138.20%
17	KMR	131.90%
18	EVR	128.20%
19	CAR	123.90%
20	AAL	116.00%
21	KAZ	111.00%
22	ACA	91.50%
23	PDL	89.30%
24	VED	87.90%
25	HOC	83.00%
26	LMI	69.60%

Table 6.4 shows that there are four extremely efficient organizations in the basic materials industry, namely SXX, TET, ZTF, and JMAT, which achieve efficiency score of 1000.00%, followed by GLEN, with an efficiency score of 611.50%. The lowest efficient organization is KAZ, with an efficiency score of 111.00%. Additionally, similar to the BCC model results in section 5.5.1.1, organization ACA is operating above average and achieves a score of 91.50%. There are four inefficient organizations: PDL (89.30%), VED (87.90%), HOC (83.00%), and LMI (69.60%).

6.6 Super-efficiency scores for Consumer Goods Industry

Forty-two organizations were included in the analysis for the consumer goods industry. The results of the BCC model show that twenty-five of these organizations are considered efficient. After conducting the super-efficiency approach while applying the BCC model and the output maximization approach, the results are consistent with the previous findings. Moreover, the super-efficiency technique provides rankings for the twenty-five efficient organizations, as shown in Table 6.5.

Table 6.5: Super efficiency scores for consumer goods industry organizations

No.	DMU	Score
1	GAW	1000.00%
2	UPGS	1000.00%
3	AEP	573.60%
4	TW.	368.60%
5	ULVR	294.70%
6	HFG	254.60%
7	PHTM	224.70%
8	BATS	195.00%
9	RB.	164.40%
10	IMB	157.00%
11	GKN	154.80%
12	CHOO	143.80%
13	DGE	134.80%
14	GLE	130.70%
15	CRST	127.20%
16	PFD	124.90%
17	ABF	119.30%
18	GFRD	116.90%
19	STCK	116.90%
20	PSN	115.60%
21	BLWY	114.60%
22	BKG	111.70%
23	GNCL	109.90%
24	BRBY	108.50%
25	BDEV	100.30%
26	TED	99.30%
27	CWK	98.70%
28	TATE	98.30%
29	MCB	98.20%
30	BRAG	97.70%
31	SGP	97.40%
32	BVIC	96.70%
33	HEAD	96.70%
34	RDW	95.00%
35	PZC	94.10%
36	CARR	93.00%
37	MCS	93.00%
38	CSP	92.80%
39	CCH	92.30%
40	BVS	91.90%
41	DCG	89.50%
42	DVO	89.00%

Table 6.5 shows that there are two extremely efficient organizations in the consumer goods industry, namely GAW and UPGS, which achieve efficiency scores of 1000.00%. They are followed by AEP, with an efficiency score of 573.60%. The lowest efficient organization is BDEV, with an efficiency score of 100.30%. Additionally, similar to the BCC model results in section 5.6.1.1, fifteen organizations are operating above the average. There are two inefficient organizations: DCG (89.50%), and DVO (89.00%).

6.7 Super-efficiency scores for Consumer Services Industry

For the consumer services industry, eighty-seven organizations were included in the analysis. The results of the BCC model show that thirty-five of them are considered efficient. After conducting the super-efficiency approach while applying the BCC model and the output maximization approach, the results are consistent with the previous findings. Moreover, the super-efficiency technique provides ranking of the thirty-five efficient organizations, as shown in Table 6.6.

Table 6.6: Super-efficiency scores for consumer service industry organizations

No.	DMU	Score
1	GOCO	1000.00%
2	HSW	1000.00%
3	OTB	1000.00%
4	RMV	1000.00%
5	STVG	1000.00%
6	TSCO	318.20%
7	ITV	313.10%
8	AUTO	287.70%
9	MOTR	275.20%
10	REL	217.10%
11	NXT	205.50%
12	UBM	198.50%
13	CPG	169.20%
14	TRS	164.50%
15	CCL	162.20%
16	TCG	161.10%
17	INF	158.60%
18	BOK	154.80%
19	SKY	151.60%
20	TUI	148.90%
21	IHT	145.60%
22	INCH	132.50%
23	FOUR	123.40%
24	DC.	114.90%
25	PDG	113.70%
26	GYM	113.10%
27	MORW	110.10%
28	LOOK	108.80%
29	ETO	108.30%
30	ZPG	107.30%
31	SBRY	105.40%
32	LCL	104.20%
33	WPP	101.40%
34	AO.	100.40%
35	JD.	100.30%
36	MKS	98.30%
37	MONY	97.60%
38	KGF	97.20%
39	EZJ	96.10%
40	WMH	94.10%
41	BME	93.90%
42	GOG	93.70%
43	TNI	93.60%
44	SMWH	93.00%
45	PETS	92.20%
46	DFS	91.60%
47	SSPG	91.30%
48	DNLM	91.20%
49	JE.	91.10%
50	MCLS	90.98%
51	WTB	90.70%
52	WIZZ	89.00%
53	SGC	88.10%
54	DOM	88.00%
55	HFD	87.60%
56	SAGA	87.20%
57	CARD	87.00%
58	SPD	86.80%
59	DEB	86.70%
60	ERM	86.50%
61	FGP	86.30%
62	MERL	85.10%
63	GKN	85.00%
64	GREG	84.80%
65	ASCL	84.20%
66	RNK	83.20%
67	MTC	82.30%
68	MAB	81.80%
69	OCDO	81.80%
70	ITE	80.90%
71	NEX	80.50%
72	RTN	80.30%
73	JDW	80.10%
74	PSON	79.30%
75	BOWL	79.20%
76	CINE	78.60%
77	BRWN	77.70%
78	HNT	76.60%
79	MARS	76.30%
80	CPR	74.40%
81	DTY	73.30%
82	SPO	73.20%
83	MLC	72.30%
84	TPT	69.60%
85	FDL	68.20%
86	MOSB	53.20%
87	BMY	51.70%

Table 6.6 shows that there are five extremely efficient organizations in the consumer services industry, namely GOCO, HSW, OTB, RMV, and STVG, which achieve efficiency scores of 1000.00%. These are followed by TSCO, with an efficiency score of 318.20%. The lowest efficient organization is JD, with an efficiency score of 100.30%. Additionally, similar to the BCC model results in section 5.7.1.1, sixteen organizations are operating above the average, while thirty-six are operating below the average or are inefficient.

6.8 Super-efficiency scores for Industrials Industry

The industrial industry includes 100 organizations. The results of the BCC model indicate that forty-six out of 100 organizations are considered efficient. After conducting the super-efficiency approach while applying the BCC model and the output maximization approach, the results are consistent with the previous findings. Moreover, the super-efficiency technique provides ranking for the forty-six efficient organizations, as shown in Table 6.7.

Table 6.7: Super efficiency scores for industrial industry organizations

No.	DMU	Score
1	AVON	1000.00%
2	CLG	1000.00%
3	CNCT	1000.00%
4	PAGE	1000.00%
5	STOB	1000.00%
6	TTG	1000.00%
7	XAR	1000.00%
8	BA.	285.00%
9	NTG	272.60%
10	IBST	231.70%
11	DLAR	230.70%
12	BNZL	225.80%
13	ESNT	213.50%
14	AA.	209.60%
15	MTO	193.60%
16	SDY	178.90%
17	CPI	178.20%
18	WIN	169.40%
19	SMDS	167.20%
20	BODY	165.60%
21	HWDN	164.40%
22	BAB	158.00%
23	ITRK	149.80%
24	CMS	144.90%
25	RNO	144.50%
26	MGGT	130.60%
27	BBY	129.50%
28	COB	129.50%
29	CKN	127.80%
30	GDWN	127.20%
31	GFS	127.00%
32	PLP	126.20%
33	VP.	124.80%
34	AHT	119.90%
35	LUCE	119.80%
36	RPS	114.30%
37	RR.	111.90%
38	BOOT	109.20%
39	RMG	109.10%
40	SHI	105.40%
41	PAYS	105.10%
42	MSLH	103.80%
43	RTRK	102.60%
44	SXS	102.50%
45	QQ.	101.10%

46	KIE	100.30%
47	FERG	99.50%
48	CTR	99.20%
49	FAN	99.00%
50	WPG	99.00%
51	GFTU	98.70%
52	TRI	98.30%
53	RPC	97.50%
54	RWI	96.50%
55	MER	96.20%
56	HSV	96.10%
57	SFR	96.10%
58	RWA	94.60%
59	RENT	94.40%
60	IWG	94.30%
61	RSHW	94.20%
62	HRG	93.70%
63	MGNS	93.70%
64	FORT	93.50%
65	TYMN	93.30%
66	SNN	93.00%
67	SMIN	92.30%
68	DPLM	92.10%
69	BBA	92.00%
70	PAY	91.80%
71	TPK	91.70%
72	XPP	91.50%
73	MRO	91.30%
74	FENR	91.10%
75	WEIR	90.90%
76	ULE	90.60%
77	COST	90.30%
78	HSS	90.30%
79	IMI	90.30%
80	IRV	90.20%
81	BRSN	90.10%
82	HAS	89.70%
83	CLLN	89.30%
84	STHR	89.30%
85	EXPN	89.20%
86	HLMA	88.50%
87	MGAM	87.80%
88	DIA	86.60%
89	SKG	86.20%
90	MNZS	85.90%
91	SNR	84.60%
92	BIFF	84.20%
93	RCDO	83.90%
94	AGK	83.60%
95	COA	82.90%
96	ECOM	82.10%
97	VSVS	82.10%
98	SPRX	80.80%
99	HILS	80.40%
100	EQN	78.80%

Table 6.7 shows that there are seven extremely efficient organizations in the industrial industry, namely AVON, CLG, CNCT, PAGE, STOB, TTG, and XAR, which achieve efficiency scores of 1000.00%, followed by BA, with an efficiency score of 285.00%. The lowest efficient organization is KIE, with an efficiency score of 100.30%. Additionally, similar to the BCC model results in section 5.8.1.1, thirty-five organizations are operating above the average, while nineteen are operating below the average or are inefficient.

Chapter Seven: Summary and Conclusion

This chapter begins with a summary of the thesis, including the research problem and the chapters of the research that was conducted to address this problem. The second section states the conclusion reached from the empirical study. The third and fourth sections present the possible implications and the possibility to generalize the findings of this study. The conclusions are linked to the responses to the original research questions. Furthermore, the final sections highlight the limitations of this research and present suggestions for future research. The recommendations present future research opportunities related to this problem, as well as the limitations of the current work.

7.1 Summary

To cope with the rapid changes in the world and the economic progression, organizations have to highlight the importance of evaluating performance and examine their efficiency levels in order to become able to modify any existing shortfalls. Several advantages of performance evaluation have been recognized in the literature, such as enhancing competitiveness between organizations within various industries, increasing the organizations' ability to determine current pitfalls, providing organizations with insights required to develop and progress, and providing stakeholders with accurate and appropriate information. Accordingly, most managers are focused on the use of techniques to evaluate performance.

Consequently, in 1992, Norton and Kaplan introduced the BSC approach as a performance measurement technique. Then, in 1996, it was evolved as a strategic technique. The BSC includes qualitative criteria and is considered as a management innovation. It combines both financial and nonfinancial criteria. Additionally, it concentrates on both short- and long-term goals of the organization.

In spite of all these advantages, there is a significant obstacle in applying the BSC, namely the absence of a baseline, standards, and a specific model to assess organizations' performance. Ramanathan and Ramanathan (2011) stated that "This problem could be avoided if an objective methodology is used in the BSC framework. No specific objective methodology is normally suggested in the BSC framework, though some tools, such as statistics, have been used in conjunction with BSC to provide an objective framework" (p.260). Additionally, Aryanezhad et al. (2011) mentioned that evaluating performance without baselines and standards is impossible and provides misleading information. Organizations also face difficulties in applying the BSC. Hence, the current study proposed to combine the BSC and DEA approaches.

As DEA relies on relative efficiency analysis, it evaluates organizations by comparing them with each other. Consequently, there is no need to determine standards and baselines. In other words, this means that the integration between DEA and BSC helps in solving one of the limitations related to applying the BSC.

Applying the combined DEA-BSC model brings numerous advantages. It provides managers with more accurate and comprehensive information. Chen and Chen (2007) stated that within the combined model, while BSC briefly evaluates the organization's performance, it provides a comprehensive view through four perspectives. Then, DEA completes the performance evaluation process by providing a more in-depth analysis based on inputs and outputs. DEA has the capability to assess the efficiency level of each organization compared to the others, identify inefficient organizations, detect both efficient and inefficient factors that can affect the productivity and efficiency level of the organization, provide potential improvements for inefficient organizations so that they can become efficient, and determine appropriate benchmarks that are required to be able to enhance the performance of an organization (Mostafa, 2007). Lastly, the combined DEA-BSC model provides a complete view of the organization's performance.

Briefly, the research journey started with an introduction to address the problem statement, the research objectives, research questions, research significance, and limitations of the research. The chapter concluded with a research outline to elaborate the destination statement for the research. In Chapter Two, an overview of the BSC and DEA was presented and the background to the research was set out. Chapter Two concluded by highlighting the advantages of applying the combined DEA-BSC model.

Chapter Three provided the literature review for the research. The literature was classified into three groups. The first group of studies reviewed addressed the relationship between BSC and organizations' performance; the second group addressed the relationship between DEA and organizations' performance. The third group reviewed previous research addressing the integration between BSC and DEA and their relationship to organizations' performance. The chapter ended with an evaluation of the literature review and the identification of gaps.

Chapter Four presented the research method, including the design of the research, showing the steps followed, including data collection, the selection of variables, the DEA model used, and finally the combined DEA-BSC model. Chapter Five then presented the results of applying the combined DEA-BSC model to various organizations within seven different industries and identified the optimal combination of variables. Chapter Six discussed the sensitivity analysis.

7.2 Conclusion

The main objective of the current study is to improve the evaluation process of organizations' performance and examine organizations' relative efficiency in seven different industries by developing a holistic research framework that combines two techniques: BSC and DEA. The literature reveals that BSC can be applied as a performance management technique for assessing an organization's performance. Furthermore, the four BSC perspectives play a leading role in linking the organization's strategies with performance measures and provide managers with insight for evaluation of organizations' performance. The current study also summarizes the shortcomings of BSC and proposes that combining it with DEA can deal with some of these limitations.

Based on the literature review and the empirical investigation, it has been concluded that the combined DEA-BSC model provides more useful information than applying each technique separately. Additionally, the findings suggest that the combined DEA-BSC model could overcome the pitfalls in existing BSC applications. For example, when applying the BSC, it is impossible to differentiate between the performances of several organizations, as the application of the BSC is not supported by a mathematical model. However, the combined DEA-BSC model in the current study enables comparison between organizations.

Furthermore, the DEA model has been shown to have the ability to generate one single efficiency score by dealing with multiple inputs and outputs. Hence, it is considered as a Total Factor Productivity. DEA is a non-parametric technique that does not require prior definition of the association between inputs and outputs. Its main consideration is to evaluate the levels of efficiency and inefficiency associated with each individual organization. By applying DEA, management can examine the overall efficiency levels and determine the required projections for converting an inefficient organization into an efficient one. Additionally, DEA provides recommendations for the management of the organization about the benchmarks that can be used. To sum up, it can be said that the suggested combined DEA-BSC model advances the individual capabilities of both DEA and BSC.

The current study explains why managers can rely on applying the combined DEA-BSC model as an analytic instrument in the decision-making process. The focal point of DEA-BSC is on featuring singular DMUs that display best practices as opposed to the central tendencies of the group as a whole. This approach enables managers to determine which areas need to be enhanced by identifying reasons for inefficiencies. Additionally, this approach produces information that is not obtainable with other techniques. For instance, it provides managers with potential improvements that will transform an inefficient organization into an efficient one. Along these lines, the combined DEA-BSC model is able to determine specific problems that the organization might face.

Applying the combined DEA-BSC model provides a comprehensive framework of an organization, as it takes into consideration financial and non-financial, short-term and long-term aspects. It also has advantages for the application of the two techniques. According to DEA, the combined model generalizes the standard treatment of the data by classifying the inputs and outputs into four groups, which represent the four BSC perspectives; whereas according to the BSC, the combined model provides a new approach to evaluate performance by using quantitative analysis. Unlike BSC, the combined DEA-BSC provides a single, comprehensive measure of performance. Moreover, it solves the problem of the interrelated nature of the BSC indicators. Table 7.1 provides a summary of the response to each of the research questions presented.

Table 7.1: Response to each of the research questions

Research Objectives	Research Questions	Response to Research Questions
1. Determining the efficient and inefficient organizations 2. Incorporating indicators of BSC for the input/output variables of DEA	1. Which organizations are considered efficient and which are inefficient?	- For each industry, the findings identified the efficient and inefficient organizations. - For instance, in the technology industry, twelve organizations out of sixteen are efficient and obtain 100% efficiency scores. Four organizations are inefficient, of which three are operating below average (less than 90%) and one operating above average (less than 100% and ≤ 90%). See Tables 5.1 and 5.2. - Hence, research question 1 has been answered positively.

3. Identifying reasons for inefficiency to assist managers to set up improvement strategies	2. What are the reasons for the inefficiency of the organizations?	- For each industry analysis, there is a section called 'return to scale' which determines the reason for the inefficiency of the organization. - For instance, in the oil and gas industry, there are three common inefficient organizations operating below the average. All these organizations are facing increasing returns to scale, which means that they should consider expanding the scale of their operations in order to benefit from higher productivity. However, the only organization that is operating above the average is obtaining decreasing returns to scale: in order to obtain a 100% efficiency score, it should consider downsizing. See Table 5.8. - Hence, research question 2 has been answered positively.
4. Solving some of the pitfalls of the BSC	3. Can the DEA-BSC model provide inefficient organizations with measurement and direction regarding the gap between their performance and the performance of efficient organizations?	- There is a section in each industry called 'potential improvements', which provides inefficient organizations with measurement and direction regarding the gap between their current status and the location of the efficient organizations. - For instance, in the health care industry, Table 5.14 shows how much each variable should increase or decrease to obtain a 100% efficiency level. These findings provide verification that the DEA-BSC model can provide inefficient organizations with a measurement tool and direction regarding the gap

		between their current status and that of efficient organizations. - Hence, research question 3 had been answered positively.
4. Solving some of the pitfalls of the BSC	4. How can the DEA-BSC model provide benchmark information to help inefficient organizations to reach efficiency?	- Results presented in the section on reference (peer) groups provide each inefficient organization with a benchmark or target set of peer efficient organizations. This helps inefficient organizations (DMUs) to become efficient: therefore, the conclusion is positive. - See, for example, Figure 5.18, which represents the reference set frequency in the basic materials industry.

Furthermore, this study reaches the following conclusions:

- Almost all organizations within the different industries pay considerable attention to the financial perspective, and thus the financial aspect has higher efficiency than the other aspects.
- According to the customer perspective, organizations should consider the amount of sales of their products and should simultaneously cooperate through appropriate marketing to improve their market share.
- From the internal process perspective, organizations should pay attention to the turnover of total assets and volume of stock and must coordinate closely with their sales departments. Furthermore, organizations should pay more attention to their common outstanding shares.
- In terms of learning and innovation, organizations should monitor profit per employee in order to avoid hiring excess employees. They should also focus on increasing the value of the intangible assets.

7.3 Implications

The current study has various implications. The findings provide a critical insight into the process of evaluating performance and the tools used, such as BSC, DEA, and the combined DEA-BSC model. It is relevant to specialists by giving them an expanded comprehension of several advanced performance measurement tools that can provide rules for future administration. Furthermore, this study has contributed to the current understanding of the combined DEA-BSC model and its ability to improve organizations' performance assessment. The current study has increased such understanding in the following ways:

First, the study framework has focused on the integration between the BSC and the DEA and the advantages of applying this combined model in assessing organizations' performance, which in turn provides pioneer reference materials for academicians conducting future research on the integration of DEA and BSC. Second, the provided framework has the ability to determine the competitive position of each organization.

Third, to the best of our knowledge, no other study has conducted cross-industry level analysis using the combined DEA-BSC model. Hence, the results of the current study provide managers in different industries with insight that allows them to evaluate their organizations' efficiency levels to improve their competitive plans and long-term objectives. Moreover, the cross-industry analysis is able to benchmark the organizations. Fourth, the findings of the current study provide managers with potential improvements that will be beneficial to intensify their competitive advantages in their own industry. It also provides potential improvements for inefficient organizations in each industry.

Fifth, the results of the current study shed light on the importance of making revisions to the process of evaluation of organizations' performance within different industries, as the combined DEA-BSC model produces efficiency scores that identify the reason for inefficiency and determine the variables that require more attention in order to improve. Additionally, the combined model provides insight about the priority of each of the BSC perspectives by providing a ranking for the four perspectives and determining which perspective has the highest impact on the performance of the organization and which has the lowest effect. Thus, the combined DEA-BSC model could be a significant technique for diagnosing potential problems and identifying their relevancy and impact on future investment decisions.

Sixth, the current study extends the application of the combined DEA-BSC model by applying it to seven different industries in the UK. Finally, the findings of the study provide an overview of the stability status of each industry by examining the efficiency scores for each industry for the period from 2012 to 2016. The findings provide a broader time horizon and take into account changes that have occurred in the results over time.

7.4 Possibilities to generalize

This study uses a DEA-BSC model to evaluate organizations' performance in seven different industries. As demonstrated in the literature, BSC can be used in any other organization. There are many published studies on this issue. Thus, it is possible to integrate BSC with DEA as long as attention is paid to determining which criteria we want to emphasize in this integrated method. Hence, the combined DEA-BSC model can be applied to any organization for which performance needs to be assessed and efficiency determined. Based on the content and reasoning of the DEA-BSC model, we can also use this model as a dependent variable to study how and why some organizations – both for-profit and non-profit organizations – are more efficient than others.

7.5 Research limitations

This study was conducted to analyse the level of performance of organizations as compared to each other, and at no instance should its results be used to characterize the behaviour of the organizations within each industry throughout the UK. The main limitations are as follows:

1. The inputs and the outputs were selected on the basis of availability of both financial and nonfinancial data for 307 organizations covering a period of five years, from 2012 to 2016. Although there are variables that can be selected that would further describe the performance of these organizations, data has not been collected to support their inclusion in the study. This is because, in order to be able to apply DEA, the same data must be available for all organizations being examined: hence, the researcher selected the most commonly available variables.

2. Apart from the shortcomings of the entire study, there are inherent defects in the DEA procedure. The DEA model requires the analyst to specify and measure all the inputs and outputs for the study. If any valid inputs or outputs are omitted, the results of the study can be biased against efficient consumers of input resources or efficient producers of outputs. The incorrect input or output causes some DMUs to be given higher efficiency standing than they actually have.

3. The rule of thumb states that the minimum number of analysed DMUs = (no. of inputs + no. of outputs) × two. This resulted in a minimum of sixteen DMUs. Consequently, the researcher limits the number of used variables in order to include all the industries; however,

both the utilities and telecommunications industries were excluded, as they had limited numbers of organizations: seven and six organizations respectively.

4. DEA provides relative efficiency scores based on the group of organizations included in the analysis: hence, all the efficiency scores provided cannot be considered to be independent of each other.

7.6 Suggestions for Future Research

Although many of the limitations of this study lead to suggestions of future research in certain areas, there are other ways in which this study can be expanded, such as the inclusion of other inputs and outputs. Future studies may want to include multiple outputs and inputs and apply a separate DEA model for each perspective. The current study is based mainly on secondary data: hence, another recommendation is to conduct a qualitative study, interviewing industry practitioners on actions that could impact results. Furthermore, future research can apply the combined DEA-BSC model to evaluate the performance of financial industries and compare between the different sub-sectors in this industry.

It would be interesting to see a more comprehensive study in this field. By continuing this thesis's evolutionary approach, future researchers could develop a more precise model for specific organizations. Other models of the DEA could be used, such as minimizing the inputs model. Future studies could also use a larger number of variables to provide more in-depth information and to determine the relationship between organizations and variables.

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Appendix A

Table (A.1) list of Technology industry organizations

No.	Organization name	Code	Sector
1	THE SAGE GROUP PLC	SGE	Software and Computer Services
2	MICRO FOCUS INTL	MCRO	Software and Computer Services
3	SOPHOS GROUP PLC	SOPH	Software and Computer Services
4	AVEVA GROUP PLC	AVV	Software and Computer Services
5	FDM GROUP	FDM	Software and Computer Services
6	COMPUTACENTER PLC	CCC	Software and Computer Services
7	Fidessa Group Plc	FDSA	Software and Computer Services
8	SDL plc	SDL	Software and Computer Services
9	Servelec Group plc	SERV	Software and Computer Services
10	Softcat plc	SCT	Software and Computer Services
11	Kainos Group plc	KNOS	Software and Computer Services
12	NCC Group plc	NCC	Software and Computer Services
13	Imagination Technologies Group plc	IMG	Technology Hardware and Equipment
14	Laird plc	LRD	Technology Hardware and Equipment
15	Nanoco Group Plc	NANO	Technology Hardware and Equipment
16	Spirent Communications plc	SPT	Technology Hardware and Equipment

Table (A.2) list of Oil & Gas industry organizations

No.	Organization name	Code	Sector
1	BP PLC	BP.	Oil and Gas Producers
2	Royal Dutch Shell Plc A Shares	RDSA	Oil and Gas Producers
3	TULLOW OIL PLC	TLW	Oil and Gas Producers
4	CAIRN ENERGY PLC	CNE	Oil and Gas Producers
5	Nostrum Oil & Gas plc	NOG	Oil and Gas Producers
6	Ophir Energy plc	OPHR	Oil and Gas Producers
7	Premier Oil Plc	PMO	Oil and Gas Producers
8	EnQuest plc	ENQ	Oil and Gas Producers
9	Exillon Energy Plc	EXI	Oil and Gas Producers
10	SOCO International Plc	SIA	Oil and Gas Producers
11	JOHN WOOD GROUP PLC	WG.	Oil Equipment and Services
12	AMEC FOSTER WHEELER	AMFW	Oil Equipment and Services
13	Hunting plc	HTG	Oil Equipment and Services
14	Petrofac	PFC	Oil Equipment and Services
15	Gulf Marine Services plc	GMS	Oil Equipment and Services
16	Cape plc	CIU	Oil Equipment and Services
17	Lamprell Plc	LAM	Oil Equipment and Services

Table (A.3) list of Health Care industry organizations

No.	Organization name	Code	Sector
1	SMITH & NEPHEW PLC	SN.	Health Care Equipment and Services
2	CONVATEC GROUP	CTEC	Health Care Equipment and Services
3	Spire Healthcare Group plc	SPI	Health Care Equipment and Services
4	Cambian Group plc	CMBN	Health Care Equipment and Services
5	Georgia Healthcare Group plc	GHG	Health Care Equipment and Services
6	UDG Healthcare plc	UDG	Health Care Equipment and Services
7	Consort Medical plc	CSRT	Health Care Equipment and Services
8	Medica Group plc	MGP	Health Care Equipment and Services
9	GLAXOSMITHKLINE	GSK	Pharmaceuticals and Biotechnology
10	ASTRAZENECA PLC	AZN	Pharmaceuticals and Biotechnology
11	SHIRE PLC	SHP	Pharmaceuticals and Biotechnology
12	BTG PLC	BTG	Pharmaceuticals and Biotechnology
13	HIKMA PHARMACEUTICALS	HIK	Pharmaceuticals and Biotechnology
14	INDIVIOR PLC (INDV)	INDV	Pharmaceuticals and Biotechnology
15	Dechra Pharmaceuticals plc	DPH	Pharmaceuticals and Biotechnology
16	Genus plc	GNS	Pharmaceuticals and Biotechnology
17	Vectura Group	VEC	Pharmaceuticals and Biotechnology
18	Circassia Pharmaceuticals plc	CIR	Pharmaceuticals and Biotechnology
19	Oxford Biomedica plc	OXB	Pharmaceuticals and Biotechnology

Table (A.4) list of Basic Materials industry organizations

No.	Organization name	Code	Sector
1	CRODA INTERNATIONAL	CRDA	Chemicals
2	JOHNSON MATTHEY PLC	JMAT	Chemicals
3	ELEMENTIS PLC	ELM	Chemicals
4	SYNTHOMER PLC	SYNT	Chemicals
5	Zotefoams plc	ZTF	Chemicals
6	Carclo plc	CAR	Chemicals
7	Treatt plc	TET	Chemicals
8	MONDI PLC	MNDI	Forestry and Paper
9	EVRAZ PLC	EVR	Industrial Metals and Mining
10	FERREXPO PLC	FXPO	Industrial Metals and Mining
11	GLENCORE PLC	GLEN	Mining
12	RIO TINTO PLC	RIO	Mining
13	BHP BILLITON PLC	BLT	Mining
14	ANGLO AMERICAN PLC	AAL	Mining
15	ANTOFAGASTA PLC	ANTO	Mining
16	RANDGOLD RESOURCES	RRS	Mining
17	KAZ MINERALS PLC	KAZ	Mining

18	VEDANTA RESOURCES	VED	Mining
19	Hochschild Mining Plc	HOC	Mining
20	Lonmin plc	LMI	Mining
21	ACACIA MINING PLC	ACA	Mining
22	Gem Diamonds Ltd	GEMD	Mining
23	Petra Diamonds Ltd	PDL	Mining
24	Sirius Minerals plc	SXX	Mining
25	Petropavlovsk plc	POG	Mining
26	Kenmare Resources plc	KMR	Mining

Table (A.5) list of consumer goods industry organizations

No.	Organization name	Code	Sector
1	GKN PLC	GKN	Automobiles and Parts
2	DIAGEO PLC	DGE	Beverages
3	COCA COLA HBC AG	CCH	Beverages
4	BRITVIC PLC	BVIC	Beverages
5	A.G. BARR PLC	BRAG	Beverages
6	Stock Spirits Group plc	STCK	Beverages
7	ASSOCIATED BRITISH	ABF	Food Producers
8	TATE & LYLE PLC	TATE	Food Producers
9	CRANSWICK PLC	CWK	Food Producers
10	DAIRY CREST GROUP	DCG	Food Producers
11	Greencore Group plc	GNCL	Food Producers
12	Devro plc	DVO	Food Producers
13	Hilton Food Group Plc	HFG	Food Producers
14	Premier Foods plc	PFD	Food Producers
15	Anglo-Eastern Plantations plc (AEP)	AEP	Food Producers
16	Carrs Group plc (CARR)	CARR	Food Producers
17	RECKITT BENCKISER GROUP	RB.	Household Goods and Home Construction
18	PERSIMMON PLC	PSN	Household Goods and Home Construction
19	BARRATT DEVELOPMENTS	BDEV	Household Goods and Home Construction
20	TAYLOR WIMPEY PLC	TW.	Household Goods and Home Construction
21	BERKELEY GROUP	BKG	Household Goods and Home Construction
22	BELLWAY PLC	BLWY	Household Goods and Home Construction
23	REDROW PLC	RDW	Household Goods and Home Construction
24	BOVIS HOMES GROUP	BVS	Household Goods and Home Construction
25	CREST NICHOLSON HOLD	CRST	Household Goods and Home Construction
26	GALLIFORD TRY PLC	GFRD	Household Goods and Home Construction
27	COUNTRYSIDE PROPERTI	CSP	Household Goods and Home Construction
28	McCarthy & Stone plc	MCS	Household Goods and Home Construction
29	Headlam Group plc	HEAD	Household Goods and Home Construction

30	McBride plc	MCB	Household Goods and Home Construction
31	MJ Gleeson plc	GLE	Household Goods and Home Construction
32	UP Global Sourcing Holdings plc	UPGS	Household Goods and Home Construction
33	Games Workshop Group	GAW	Leisure Goods
34	Photo-me International plc	PHTM	Leisure Goods
35	UNILEVER (UK)	ULVR	Personal Goods
36	BURBERRY GROUP	BRBY	Personal Goods
37	Jimmy Choo plc	CHOO	Personal Goods
38	PZ Cussons Plc	PZC	Personal Goods
39	Supergroup	SGP	Personal Goods
40	Ted Baker	TED	Personal Goods
41	BRITISH AMERICAN TOB	BATS	Tobacco
42	IMPERIAL BRANDS	IMB	Tobacco

Table (A.6) list of consumer service industry organizations

No.	**Organization name**	**Code**	**Sector**
	TESCO PLC	TSCO	Food and Drug Retailers
2	WM. MORRISON SUPERMT	MORW	Food and Drug Retailers
3	J SAINSBURY PLC	SBRY	Food and Drug Retailers
4	BOOKER GROUP PLC	BOK	Food and Drug Retailers
5	GREGGS PLC	GREG	Food and Drug Retailers
6	OCADO GROUP PLC	OCDO	Food and Drug Retailers
7	MCCOLL'S RETAIL GP.	MCLS	Food and Drug Retailers
8	NEXT PLC	NXT	General Retailers
9	KINGFISHER PLC	KGF	General Retailers
10	MARKS & SPENCER	MKS	General Retailers
11	DIXONS CARPHONE PLC	DC.	General Retailers
12	JUST EAT PLC	JE.	General Retailers
13	INCHCAPE PLC	INCH	General Retailers
14	B&M EUROPEAN	BME	General Retailers
15	DIGNITY PLC	DTY	General Retailers
16	JD SPORTS FASHION	JD.	General Retailers
17	PETS AT HOME	PETS	General Retailers
18	SAGA PLC	SAGA	General Retailers
19	SPORTS DIRECT INTER	SPD	General Retailers
20	WH SMITH PLC	SMWH	General Retailers
21	N BROWN GROUP PLC	BRWN	General Retailers
22	CARD FACTORY PLC	CARD	General Retailers
23	Dunelm Group Plc	DNLM	General Retailers
24	AO World plc	AO.	General Retailers
25	Debenhams plc	DEB	General Retailers

26	Halfords	HFD	General Retailers
27	Pendragon	PDG	General Retailers
28	Carpetright plc	CPR	General Retailers
29	DFS Furniture Plc	DFS	General Retailers
30	Findel plc	FDL	General Retailers
31	Lookers Plc	LOOK	General Retailers
32	Moss Bros Group plc	MOSB	General Retailers
33	MOTHERCARE	MTC	General Retailers
34	Motorpoint plc	MOTR	General Retailers
35	Topps Tiles plc	TPT	General Retailers
36	WPP PLC	WPP	Media
37	RELX PLC	REL	Media
38	SKY PLC	SKY	Media
39	ITV PLC	ITV	Media
40	INFORMA PLC	INF	Media
41	PEARSON PLC	PSON	Media
42	RIGHTMOVE PLC	RMV	Media
43	AUTO TRADER	AUTO	Media
44	UBM PLC	UBM	Media
45	ASCENTIAL PLC	ASCL	Media
46	Euromoney Institutional Investors plc	ERM	Media
47	Moneysupermarket.Com	MONY	Media
48	ZPG plc	ZPG	Media
49	Entertainment One Ltd	ETO	Media
50	GoCompare.com Plc	GOCO	Media
51	Tarsus Group Plc	TRS	Media
52	Trinity Mirror plc	TNI	Media
53	4imprint Group plc	FOUR	Media
54	Bloomsbury Publishing plc	BMY	Media
55	Huntsworth plc	HNT	Media
56	ITE Group plc	ITE	Media
57	STV Group plc	STVG	Media
58	COMPASS GROUP PLC	CPG	Travel and Leisure
59	Intercontinental Hotels Group	IHG	Travel and Leisure
60	CARNIVAL PLC	CCL	Travel and Leisure
61	WHITBREAD PLC	WTB	Travel and Leisure
62	EASYJET PLC	EZJ	Travel and Leisure
63	MERLIN ENTERTAIN	MERL	Travel and Leisure
64	WILLIAM HILL PLC	WMH	Travel and Leisure
65	LADBROKES PLC	LCL	Travel and Leisure
66	SSP GROUP LIMITED	SSPG	Travel and Leisure
67	FIRSTGROUP PLC	FGP	Travel and Leisure

68	GREENE KING PLC	GKN	Travel and Leisure
69	THOMAS COOK GROUP	TCG	Travel and Leisure
70	J D WETHERSPOON	JDW	Travel and Leisure
71	WIZZ AIR	WIZZ	Travel and Leisure
72	CINEWORLD GROUP PLC	CINE	Travel and Leisure
73	Domino's Pizza Group plc	DOM	Travel and Leisure
74	Millennium & Copthorne Hotels plc	MLC	Travel and Leisure
75	Mitchells & Butlers Plc	MAB	Travel and Leisure
76	National Express	NEX	Travel and Leisure
77	Rank Group	RNK	Travel and Leisure
78	Stagecoach Group plc	SGC	Travel and Leisure
79	Go Ahead Group	GOG	Travel and Leisure
80	Marstons plc	MARS	Travel and Leisure
81	Restaurant Group	RTN	Travel and Leisure
82	Sportech Plc	SPO	Travel and Leisure
83	Gym Group plc	GYM	Travel and Leisure
84	Hollywood Bowl Group Plc	BOWL	Travel and Leisure
85	Hostelworld Group plc	HSW	Travel and Leisure
86	On the Beach Group plc	OTB	Travel and Leisure
87	TUI AG	TUI	Travel and Leisure

Table (A.7) list of industrial industry organizations

No.	**Organization name**	**Code**	**Sector**
1	BAE SYSTEMS	BA.	Aerospace and Defence
2	ROLLS-ROYCE	RR.	Aerospace and Defence
3	COBHAM PLC	COB	Aerospace and Defence
4	MEGGITT PLC	MGGT	Aerospace and Defence
5	QINETIQ GROUP	QQ.	Aerospace and Defence
6	SENIOR PLC	SNR	Aerospace and Defence
7	ULTRA ELECTRONICS	ULE	Aerospace and Defence
8	Avon Rubber plc	AVON	Aerospace and Defence
9	MELROSE	MRO	Construction and Materials
10	KIER GROUP PLC	KIE	Construction and Materials
11	BALFOUR BEATTY PLC	BBY	Construction and Materials
12	Ibstock plc	IBST	Construction and Materials
13	Boot (Henry) plc (BOOT)	BOOT	Construction and Materials
14	Forterra plc	FORT	Construction and Materials
15	Marshalls Plc	MSLH	Construction and Materials
16	Morgan Sindall Group Plc	MGNS	Construction and Materials
17	Polypipe Group plc	PLP	Construction and Materials
18	Volution Group plc	FAN	Construction and Materials

19	Costain Group plc	COST	Construction and Materials
20	Tyman Plc	TYMN	Construction and Materials
21	RENISHAW PLC	RSHW	Electronic and Electrical Equipment
22	HALMA PLC	HLMA	Electronic and Electrical Equipment
23	MORGAN ADVANCED	MGAM	Electronic and Electrical Equipment
24	SPECTRIS PLC	SXS	Electronic and Electrical Equipment
25	Dialight plc	DIA	Electronic and Electrical Equipment
26	TT Electronics plc	TTG	Electronic and Electrical Equipment
27	Xaar	XAR	Electronic and Electrical Equipment
28	Luceco Plc	LUCE	Electronic and Electrical Equipment
29	XP Power Limited	XPP	Electronic and Electrical Equipment
30	SMITHS INDUSTRIES	SMIN	General Industrials
31	DS SMITH PLC	SMDS	General Industrials
32	COATS GROUP PLC	COA	General Industrials
33	VESUVIUS PLC	VSVS	General Industrials
34	RPC GROUP PLC	RPC	General Industrials
35	Smurfit Kappa Group Plc	SKG	General Industrials
36	BODYCOTE	BODY	Industrial Engineering
37	ROTORK PLC	RTRK	Industrial Engineering
38	SPIRAX-SARCO ENGIN.	SPRX	Industrial Engineering
39	WEIR GROUP PLC	WEIR	Industrial Engineering
40	IMI PLC	IMI	Industrial Engineering
41	Hill & Smith Holdings plc.	HILS	Industrial Engineering
42	Fenner plc	FENR	Industrial Engineering
43	Goodwin plc	GDWN	Industrial Engineering
44	Renold plc	RNO	Industrial Engineering
45	Severfield plc	SFR	Industrial Engineering
46	Trifast	TRI	Industrial Engineering
47	ROYAL MAIL PLC	RMG	Industrial Transportation
48	BBA AVIATION	BBA	Industrial Transportation
49	CLARKSON PLC	CKN	Industrial Transportation
50	Stobart Group Ltd	STOB	Industrial Transportation
51	Clipper Logistics plc	CLG	Industrial Transportation
52	Wincanton	WIN	Industrial Transportation
53	EXPERIAN PLC	EXPN	Support Services
54	BABCOCK INT'L GROUP	BAB	Support Services
55	WOLSELEY PLC	FERG	Support Services
56	INTERTEK GROUP	ITRK	Support Services
57	ASHTEAD GROUP PLC	AHT	Support Services
58	BUNZL PLC	BNZL	Support Services
59	WORLDPAY GROUP PLC	WPG	Support Services
60	G4S PLC	GFS	Support Services

61	RENTOKIL INITIAL PLC	RENT	Support Services
62	TRAVIS PERKINS PLC	TPK	Support Services
63	AGGREKO PLC	AGK	Support Services
64	BERENDSEN PLC	BRSN	Support Services
65	CAPITA PLC	CPI	Support Services
66	HOWDEN JOINERY	HWDN	Support Services
67	AA PLC	AA.	Support Services
68	CARILLION PLC	CLLN	Support Services
69	ELECTROCOMPONENTS	ECOM	Support Services
70	ESSENTRA PLC	ESNT	Support Services
71	HAYS PLC	HAS	Support Services
72	HOMESERVE PLC	HSV	Support Services
73	IWG PLC	IWG	Support Services
74	MITIE GROUP PLC	MTO	Support Services
75	PAYSAFE GROUP	PAYS	Support Services
76	Diploma plc	DPLM	Support Services
77	Grafton Group	GFTU	Support Services
78	PageGroup plc	PAGE	Support Services
79	Sanne Group plc	SNN	Support Services
80	Sig plc	SHI	Support Services
81	Equiniti Group plc	EQN	Support Services
82	HSS Hire Group plc	HSS	Support Services
83	Interserve plc	IRV	Support Services
84	Northgate Plc	NTG	Support Services
85	Paypoint Plc	PAY	Support Services
86	Ricardo plc	RCDO	Support Services
87	BIFFA PLC	BIFF	Support Services
88	Charles Taylor plc	CTR	Support Services
89	Communisis plc	CMS	Support Services
90	Connect Group plc	CNCT	Support Services
91	De La Rue plc	DLAR	Support Services
92	Hogg Robinson Group Plc	HRG	Support Services
93	Mears Group plc	MER	Support Services
94	Menzies (John) plc	MNZS	Support Services
95	Renewi Plc	RWI	Support Services
96	Robert Walters plc	RWA	Support Services
97	Rps Group plc	RPS	Support Services
98	Speedy Hire plc	SDY	Support Services
99	Sthree Plc	STHR	Support Services
100	Vp plc	VP.	Support Services

Appendix B

Table (B.1) Potential improvements in consumer goods industry at 2016

Category	**Variable**	**CSP**	**CARR**	**MCS**	**PZC**	**RDW**	**BVIC**	**HEAD**	**SGP**	**BRAG**	**MCB**	**TATE**	**CWK**	**TED**
	Efficiency score	92.80%	92.96%	93.04%	94.11%	95%	96.73%	96.75%	97.36%	97.73%	98.22%	98.30%	98.69%	99.28%
Input	NE	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	TOE	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	TA	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	TC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Financial	OI	54%	87%	49%	49%	28%	27%	57%	25%	14%	37%	97%	22%	6%
	NI	94%	131%	156%	165%	135%	136%	149%	152%	113%	97%	54%	33%	8%
customer	NS	118%	199%	172%	125%	279%	113%	177%	113%	211%	177%	112%	145.3%	176%
	RMS	143%	184%	118%	105%	145%	113%	152%	161%	12%	187%	139%	153%	164%
Internal process	TAT	12%	64%	25%	16%	79%	26%	18%	9%	17%	70%	22%	39%	16%
	CSO	8%	72%	8%	6%	5%	3%	7%	16%	51%	2%	3%	25%	6%
Learning and growth	TIA	8%	8%	8%	6%	5%	3%	3%	3%	2%	2%	2%	1%	1%
	PPEM	8%	8%	8%	6%	5%	3%	3%	3%	2%	2%	2%	1%	1%
	Reference set	RB. PSN TW. GLE UPGS GAW	HFG PSN UPGS PHTM	DGE RB. PSN TW. GLE PHTM	HFG RB. TW. PHTM	PSN TW. BKG CRST GAW	HFG RB. TW. UPGS GAW PHTM	HFG RB. PSN UPGS	HFG AEP PHTM BRBY	RB. PSN UPGS GAW PHTM BRBY	HFG RB. UPGS PHTM	HFG TW. BLWY IMB	HFG AEP PHTM BRBY	HFG PSN PHTM BRBY

Table (B.2) Potential improvements in consumer services industry at 2016

Category	**Variable**	**MKS**	**MONY**	**BME**	**SMWH**	**KGF**	**DNLM**	**EZJ**	**GOG**	**WMH**	**TNI**	**SSPG**	**PETS**	**DFS**
	Efficiency score	98.25	97.58	97.57	97.46	97.16	96.07	96.06	94.84	94.7	93.6	93.42	92.23	91.64
Input	NE	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	TOE	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	TA	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	TC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Financial	OI %	26.2	8.4	28.2	24.1	46.1	27.9	49	191.1	37.6	75.8	117.4	65.3	91
	NI%	49	4.4	19.9	15.9	54.7	25.4	4.1	194.5	34.7	145.3	150.3	59.5	75.1
customer	NS%	1.8	2.5	2.5	2.6	2.9	4.1	4.1	5.4	5.6	14.2	7	8.4	9.1
	RMS%	1.8	2.5	2.5	2.6	2.9	4.1	4.1	5.4	5.6	14.2	7	8.4	9.1
Internal process	TAT%	19.2	131	2.5	112.2	5.8	71.9	12.7	48.2	141.8	422.8	176.6	357	274.1
	CSO%	1.8	2.5	2.5	2.6	2.9	4.1	718.1	1427	5.6	6.8	7	31.1	128.9
Learning and growth	TIA%	56.2	2.5	2.5	39.3	2.9	211.5	396.4	144.7	5.6	6.8	7	8.4	9.1
	PPEM%	396.2	8.6	1760.4	446.8	520.1	914.7	39.8	433.4	829.4	2333.6	2067.1	490.2	455.2
	Reference set	TSCO SBRY NXT REL ITV	MOTR RMV AUTO GOCO STVG	DC. PDG MOTR REL INF AUTO CPG	NXT PDG MOTR RMV	TSCO SBRY NXT REL ITV CPG	NXT PDG MOTR RMV	INCH REL SKY ITV	NXT PDG LOOK MOTR	DC. MOTR REL INF AUTO CPG	REL RMV GOCO STVG	NXT PDG MOTR REL AUTO CPG	MOTR REL INF AUTO CPG	MOTR REL RMV AUTO CPG

Table B.2 continued

Category	Variable	JE.	HFD	SGC	WIZZ	DOM	GREG	DEB	SAGA	SPD	CARD	ERM	FGP	MERL
	Efficiency score	**91.15**	**89.97**	**89.75**	**89.02**	**88.86**	**87.76**	**87.67**	**87.16**	**87.02**	**87.01**	**86.48**	**86.31**	**85.07**
Input	NE	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	TOE	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	TA	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	TC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Financial	OI %	66.6	134.1	230.4	74.9	54.4	155.2	251.3	72.8	164.8	66.7	74.4	332.2	79.9
	NI%	38	132.1	377.7	38.5	36.4	174.8	261.9	47.5	77.4	58.1	251.7	724	60.3
customer	NS%	15.6	11.1	11.4	12.3	12.5	13.9	14.1	14.7	14.9	14.9	15.6	15.9	17.6
	RMS%	15.6	11.1	11.4	12.3	12.5	13.9	14.1	14.7	14.9	14.9	15.6	15.9	17.6
Internal process	TAT%	154.4	227.6	14.9	256.7	93.4	119.3	21.5	67.4	57.7	134.5	619.8	41.4	40.9
	CSO%	9.7	11.1	11.4	1853.8	12.5	13.9	14.1	14.7	88.9	136.2	116.9	15.9	17.6
Learning and growth	TIA%	9.7	11.1	11.4	9965.4	745.1	264.9	14.1	14.7	124.4	14.9	15.6	41.8	17.6
	PPEM%	117.4	2195	608.2	193.6	106.9	4754.3	3263.3	228.9	428.6	1583.3	1182.3	3804.2	413
	Reference set	MOTR INF AUTO ZPG	NXT MOTR REL RMV AUTO CPG	NXT JD. PDG ITV CPG	INCH MOTR ITV RMV	JD. PDG MOTR RMV AUTO GOCO	NXT PDG MOTR RMV	NXT PDG REL ITV RMV AUTO CPG	ITV INF AUTO IHT	NXT INCH ITV RMV	MOTR INF AUTO CPG	MOTR REL INF RMV GOCO	NXT REL ITV CPG	ITV INF AUTO IHT

Table B.2 continued

Category	Variable	GKN	OCDO	ASCL	RNK	MTC	MAB	RTN	ITE	NEX	JDW	PSON	BOWL	CINE
	Efficiency score	**84.97**	**84.77**	**84.23**	**83.7**	**83.22**	**81.82**	**81.15**	**80.9**	**80.5**	**80.13**	**79.29**	**79.19**	**78.62**
Input	NE	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	TOE	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	TA	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	TC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Financial	OI %	93.5	-753.4	106.2	167.4	598.3	145.7	208.5	187.9	275.1	360.6	600.3	149.1	200.9
	NI%	153.9	1049.8	349.2	117.9	1836.7	463.3	-567.3	-482.5	309.6	631.8	-514.8	2725.7	195.2
customer	NS%	17.7	18	18.7	19.5	20.2	22.2	23.2	23.6	24.2	24.8	26.1	26.3	27.2
	RMS%	17.7	18	18.7	19.5	20.2	22.2	23.2	23.6	24.2	24.8	26.1	26.3	27.2
Internal process	TAT%	45.1	44.2	170.4	215.7	85.8	25.7	106.1	276.5	190.2	118.5	66.9	149	456.4
	CSO%	85.4	18	27.9	19.5	55.5	47.3	23.2	23.6	24.2	24.8	79.4	26.3	27.2
Learning and growth	TIA%	123.8	18	18.7	19.5	20.2	34080	23.2	23.6	24.2	368.5	104.1	26.3	27.2
	PPEM%	384	8315.6	724.1	2610	1175.7	2127.5	8187.8	1144.2	3612.3	6177.3	-149.2	1175.9	2735.6
	Reference set	REL IHT	NXT JD. PDG RMV AUTO CPG	MOTR INF RMV AUTO ZPG	NXT MOTR REL RMV AUTO CPG	NXT PDG RMV CPG TCG	REL IHT	NXT JD. RMV AUTO CPG	REL INF RMV AUTO GOCO TRS	NXT REL ITV RMV IHT	NXT ITV RMV IHT	NXT REL IHT	MOTR INF RMV ZPG GOCO HSW	NXT REL RMV AUTO CPG

Table B.2 continued

Category	Variable	BRWN	HNT	MARS	CPR	DTY	SPO	MLC	TPT	FDL
	Efficiency score	**78.07**	**76.61**	**76.33**	**76.2**	**73.29**	**73.22**	**72.34**	**72.01**	**68.41**
Input	NE	0%	0%	0%	0%	0%	0%	0%	0%	0%
	TOE	0%	0%	0%	0%	0%	0%	0%	0%	0%
	TA	0%	0%	0%	0%	0%	0%	0%	0%	0%
	TC	0%	0%	0%	0%	0%	0%	0%	0%	0%
Financial	OI %	392.4	323.4	162.6	819.9	112.3	242	237.7	396.7	546.8
	NI%	283.6	-376.6	275.3	1134.8	163.8	176.2	283.7	424.4	1721.5
customer	NS%	28.1	30.5	31	31.2	36.4	36.6	38.2	38.9	46.2
	RMS%	28.1	30.5	31	31.2	36.4	36.6	38.2	38.9	46.2
Internal process	TAT%	255.8	143.6	90	113.5	57.1	165.2	194.4	69.4	278.9
	CSO%	201.2	30.5	31	170	1717.5	36.6	38.2	38.9	349.8
Learning and growth	TIA%	169.8	30.5	246.8	31.2	36.4	36.6	874.3	300.4	181.2
	PPEM%	1099	-802.1	1338	7784.4	629.1	267.5	697.6	2237.1	4349.2
	Reference set	NXT INCH ITV RMV	MOTR RMV AUTO ZPG GOCO HSW	ITV AUTO IHT	PDG MOTR REL RMV CPG TCG	REL INF AUTO IHT	RMV AUTO ZPG GOCO TRS HSW	ITV AUTO IHT	JD. MOTR RMV GOCO	NXT INCH ITV RMV

Table (B.3) Potential improvements in industrial industry at 2016

Category	Variable	FERG	CTR	FAN	WPG	GFTU	TRI	RPC	RWI	MER	SFR	HSV	RWA	RENT
	Efficiency score	**99.47**	**99.2**	**99.02**	**99.01**	**98.68**	**98.31**	**97.55**	**96.51**	**96.23**	**96.14**	**96.12**	**94.65**	**94.4**
Input	NE	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	TOE	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	TA	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	TC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Financial	OI %	113.4	188.4	102.8	18.1	115.8	21.4	24.7	137.5	204.2	146.9	147.9	168.1	199.4
	NI%	111.5	186.6	169.3	159.9	120.4	180.1	112.5	115.7	226.8	161.4	114	104.4	134
customer	NS%	0.5	0.8	1	1	1.3	1.7	2.5	3.6	3.9	4	4	5.7	5.9
	RMS%	0.5	0.8	1	1	1.3	1.7	2.5	3.6	3.9	4	4	5.7	5.9
Internal process	TAT%	27.6	0.8	42.2	16.9	17.4	42.5	6.7	10.6	10.4	7.9	11.3	26.9	5.9
	CSO%	29.7	0.8	256	1	4.5	1.7	29.5	18	18.8	4	4	19.8	95.9
Learning and growth	TIA%	0.5	0.8	1	3.3	1.3	32.7	34.1	16.7	33.3	4	4	5.7	5.9
	PPEM%	24.7	22.4	17.6	21.9	9.2	25.6	59.1	55.1	29.7	40.4	4	135.5	21.1
	Reference set	WIN BAB ITRK CPI AA.	AVON PLP BODY ESNT MTO CMS DLAR	MSLH ESNT CNCT SDY	BA. BAB AA. ESNT	XAR CPI CMS SDY	BA. BAB AA. ESNT	BA. BAB ITRK AA.	CPI ESNT NTG CNCT SDY	CLG CPI ESNT CMS	AVON XAR BODY RNO PAGE NTG	IBST BODY WIN BNZL CPI HWDN ESNT CNCT	PLP WIN SHI CMS	WIN BAB ITRK AHT AA. ESNT

Table B.3 continued

Category	Variable	MRO	FENR	WEIR	ULE	HSS	IMI	COST	HAS	STHR	CLLN	EXPN	HLMA	MGAM
	Efficiency score	**91.29**	**91.1**	**90.88**	**90.56**	**90.34**	**90.33**	**90.28**	**89.68**	**89.29**	**89.28**	**89.19**	**88.55**	**87.76**
Input	NE	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	TOE	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	TA	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	TC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Financial	OI %	352.5	189.7	181.6	111.4	469.6	185	102.5	183.9	184.6	386.5	218.2	119.4	122.3
	NI%	-177.7	9.8	10	10.4	-231.7	72	238.8	11.5	15.2	296.3	51.5	44.1	415.9
customer	NS%	9.5	9.8	10	10.4	10.7	10.7	10.8	11.5	12	12	12.1	12.9	14
	RMS%	9.5	9.8	10	10.4	10.7	10.7	10.8	11.5	12	12	12.1	12.9	14
Internal process	TAT%	64.9	14.9	42.3	34.3	49.1	19.3	47.6	41.1	16.1	13.6	15.4	27.3	38.6
	CSO%	66.3	13.5	13.1	40.7	72	21.4	21.2	11.5	29.2	30.1	74.9	41.7	44.4
Learning and growth	TIA%	9.5	33.1	10	10.4	10.7	10.7	10.8	11.5	14.7	12	12.1	62.4	14
	PPEM%	-15.5	52	18.9	10.4	-17.8	51.6	20.9	11.5	12	12.6	18.5	53.1	32.6
	Reference set	BA. CLG AA. ESNT	TTG XAR LUCE NTG	WIN ITRK CPI HWDN AA. ESNT	IBST WIN CPI HWDN ESNT PAYS NTG	CPI AA. ESNT CMS	AVON CPI HWDN NTG CMS	AVON PLP WIN CMS	AVON IBST BODY WIN CPI HWDN NTG CNCT	LUCE HWDN PAGE NTG	ITRK CPI HWDN ESNT NTG	BA. WIN AHT AA.	CPI HWDN AA. CNCT	ITRK CPI HWDN AA. ESNT

Table B.3 continued

Category	Variable	IWG	RSHW	MGNS	HRG	FORT	TYMN	SNN	SMIN	DPLM	BBA	PAY	TPK	XPP
	Efficiency score	**94.27**	**94.23**	**93.75**	**93.67**	**93.46**	**93.3**	**92.96**	**92.33**	**92.14**	**91.96**	**91.77**	**91.68**	**91.5**
Input	NE	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	TOE	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	TA	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	TC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Financial	OI %	120.9	33	46.6	203.8	161.3	139.4	227.2	103	158.1	160.5	181.5	157.5	155.4
	NI%	116.1	114.1	161.7	175.7	117	117.2	-211.9	137	150.2	118.7	167.4	148.2	101.7
customer	NS%	6.1	6.1	6.7	6.8	7	7.2	7.6	8.3	8.5	8.7	9	9.1	9.3
	RMS%	6.1	6.1	6.7	6.8	7	7.2	7.6	8.3	8.5	8.7	9	9.1	9.3
Internal process	TAT%	43.3	43.5	40.3	24.7	7	28.7	34.7	47.5	72.1	38.7	9	44	9.3
	CSO%	15.6	6.1	6.7	8.2	7	18.2	68.9	8.3	21.6	8.1	9	81.2	56.1
Learning and growth	TIA%	6.1	6.1	6.7	6.8	7	94.5	7.6	84.3	8.5	8.7	9	13.4	9.3
	PPEM%	35.4	6.1	6.7	845.7	7	22	16.9	75.7	48.6	8.7	19.4	12.7	53.1
	Reference set	CPI HWDN AA. ESNT CMS	AVON XAR BODY WIN CPI HWDN PAGE	AVON PLP XAR WIN CPI HWDN ESNT	AVON CPI HWDN CMS	AVON IBST BOOT CPI HWDN ESNT PAYS NTG SDY	LUCE RTRK ITRK CPI	ITRK CPI HWDN AA. ESNT	BA. WIN GFS AA. ESNT	WIN ITRK HWDN AA. ESNT	AVON IBST WIN HWDN MTO PAGE NTG	AVON CPI HWDN CMS	IBST ITRK BNZL ESNT	WIN ITRK HWDN AA. SDY

Table B.3 continued

Category	Variable	DIA	SKG	MNZS	SNR	BIFF	RCDO	AGK	COA	ECOM	VSVS	SPRX
	Efficiency score	**86.59**	**86.19**	**85.86**	**84.6**	**84.16**	**83.93**	**83.57**	**82.89**	**82.08**	**82.07**	**80.83**
Input	NE	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	TOE	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	TA	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	TC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Financial	OI %	375.6	106.1	305.9	256.4	259.7	431.1	158.3	238.3	263.8	202.6	279.4
	NI%	278.3	116	-185	108.3	118.8	-113.9	154.9	167.4	-312.3	188.2	120.2
customer	NS%	15.5	16	16.5	18.2	18.8	19.2	19.7	20.6	21.8	21.8	23.7
	RMS%	15.5	16	16.5	18.2	18.8	19.2	19.7	20.6	21.8	21.8	23.7
Internal process	TAT%	23.5	48.8	25.6	58.2	18.9	35.1	70	43.9	57.7	21.8	26.4
	CSO%	61.7	39.5	16.5	23.7	18.8	14.2	25.3	16.9	12.6	69.1	19.9
Learning and growth	TIA%	15.5	72.3	63.2	18.2	21.9	19.2	38.4	20.6	21.8	21.8	23.7
	PPEM%	24.1	30.1	-49.5	11.8	19.9	-12.9	14	64.3	-23.7	12.3	18.4
	Reference set	AVON CPI HWDN CMS	LUCE ITRK CPI HWDN	BODY ITRK BNZL HWDN ESNT NTG	AVON CPI HWDN CMS	AVON HWDN PAGE NTG CNCT	ITRK CPI HWDN ESNT NTG	ITRK CPI HWDN	ITRK CPI HWDN AA. ESNT	ITRK CPI HWDN ESNT NTG	ITRK CPI HWDN AA. SDY	WIN ITRK HWDN AA. ESNT