A Multicriteria Framework for Benchmarking Sustainability Performance of Organizations

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Abstract

A Multicriteria Framework for Benchmarking Sustainability Performance of Organizations

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Sustainability involves meeting the needs of present generation without compromising the requirements of future generations. It involves focus on three main pillars: economic, environmental and social for realizing overall performance. Sustainability assessment is very essential for business organizations to improve their competition capacity. Majority of them are moving towards sustainability practices for corporate progress and improving the business appearance for long term effectiveness, thereby receiving economic benefits as well.

In this thesis, we propose a multi-criteria framework for benchmarking sustainability performance of organizations. The indicators for evaluation are obtained using Sustainalytics database. Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) and Data Envelopment Analysis (DEA) are used to generate sustainability rankings and determine targets for improvement. The proposed techniques are applied to evaluate performance of 24 companies in two major sectors: manufacturing and service. The selected companies come from the Canadian market. The results of TOPSIS study show manufacturing sector to be doing better than the service sector with average Relative Closeness (C_i) values as 0.5 and 0.36 respectively. The DEA method identified 10 inefficient companies in each sector and provided targets for improvement.

Future work can involve integration of financial Key Performance Indicators (KPIs), cross-sector investigation and involvement of Multi-Criteria Decision Making (MCDM) techniques such as Analytic Hierarchy Process (AHP) for criteria weighting in the proposed study.

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List of Abbreviations

AHP - Analytic Hierarchy Process

ANP - Analytic Network Process

BPM - Business Performance Measurement

BSC - Balanced Scorecard

C_i - It delegates Relative Closeness in TOPSIS

CDP - Carbon Disclose Project

CK - Corporate Knights

CSM - Corporate Sustainability Management

CSR - Corporate Social Responsibility

DEA - Data Envelopment Analysis

DJSI - Dow Jones Sustainability Index

DMUs – Decision Making Units

ESG - Environment, Social and Governance

GRI - Global Reporting Initiative

ISO - International Organization for Standardization

KPIs - Key Performance Indicators

LHS - Left-Hand-Side

MCDM - Multi-Criteria Decision Making (MCDM)

NDM - Normalized Decision Matrix

NIS - Negative Ideal Solution

PEST - Political, Economic, Social and Technological

PIS - Positive Ideal Solution

Q – It delegates Coefficient score in DEA

RHS - Right-Hand-Side

SBSC - Sustainability Balanced Scorecard

SC - Supply Chain

TBL – Triple Bottom Line

TOPSIS - Technique for Order Performance by Similarity to Ideal Solution

WCED - World Commission on Environment and Development

Chapter 1:

Introduction

1.1. Background

"Sustainability is about improving our standard of living by protecting human health, conserving the environment, using resources efficiently and advancing long-term economic competitiveness" (Sustainable Development, 2017).

There is no doubt extra costs occur when organizations start the transformation towards implementing green strategies. Regardless of the ultimate propose of the green initiatives companies are undertaking, adoption of green/sustainable practices may initially result in reduction of financial benefits, increasing the processing costs and slowing down the market growth. However, once the environmental management system is well developed, long term benefits along with several business advantages may compensate the initial cost.

As Pryce (2002) puts it, five major elements exert pressure on organizations to engage them in more socially and environmentally conscious operations. These factors are: customer pressure, changes in business procurement, government legislation and pressure, the rise of socially responsible investment, and the changing expectations of employees.

Depending upon the organizational culture, the process of incorporating the aforementioned drivers into strategic sustainability behavior encounters different responses including: resistant, reactive, anticipatory, and innovation-based to sustainability-rooted (Klewitz & Hansen, 2014). Unless it is truly part of the fundamentals of a corporate strategy, corporate social responsibility has no real meaning for an organization. Many initiatives have been put forth by organizations in this regard. For example, green design, green procurement, green production, green distribution and warehousing, and reverse logistics etc. These initiatives have not only helped achieve environmental goals but also assisted in business performance improvement and gaining competitive edge in the market.

Therefore, organizations are more and more interested in developing their sustainability performance. Sustainability performance measurement meets this need by providing corporations with information needed to help in the short and long-term management, controlling, planning, and performance of the economic, environmental, and social activities carried out by the corporation (Medel-González *et al.,* 2016). A critical element of this activity is identification of measurement metrics that synchronizes the organizational effort towards sustainable development. GRI (Global Reporting Initiative), DJ (Dow Jones), CK (Corporate Knights) and Sustainalytics are examples of few initiatives who provide a comprehensive set of Key Performance Indicators for corporate sustainability measurement.

1.2. Problem Definition

Our goal in this thesis is to develop a framework for benchmarking sustainability performance of organizations. This involves:

1. Identification of KPIs, criteria or indicators for measuring sustainability performance of organizations
2. Development of a benchmarking model based on a multi-criteria framework and the selected KPIs to rank the sustainability performance of organizations
3. Execute the benchmarking model using real data and generate recommendations

1.3. Thesis Outline

This thesis is organized as follows:

Chapter 1 presents the objectives of the research and structure of the thesis.

Chapter 2 contains literature review on Balanced Scorecard, Key Performance Indicators (KPIs), Multi-Criteria Decision Making techniques and their applications in sustainability planning.

Chapter 3 presents the details of Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) and Data Envelopment Analysis (DEA) used in our thesis.

Chapter 4 presents the numerical application of TOPSIS and DEA methodologies.

Chapter 5 presents the conclusions, and recommendations for future research.

Chapter 2:

Literature Review

2.1. Business Performance Measurement (BPM)

Business performance measurement helps organizations to monitor, communicate, and analyze information and trends, enabling them to review their exercises. It is thus essential for recognizing areas for improvement, accomplishing strategic goals, and benchmarking performance in relation to industry standards and competitors (Reefke & Trocchi, 2013).

The aims must be compatible with the current corporate culture and vision, and must be produced with the contribution of various departments. The goal should be to build on strengths in order to create opportunities, and to minimize weaknesses in order to avoid hazards in the future (Panayiotou, Aravossis, & Moschou, 2009).

Single-measure based gap analysis is often used as a crucial method in performance evaluation and benchmarking. However, it is rare that one single measure can serve the purpose of performance evaluation. Single output to input financial ratios, such as, return on investment (ROI) and return on sales (ROS) may be used as indices to describe the financial performance. However, they are unsatisfactory discriminants of “best-practice”, and therefore not sufficient to evaluate operating efficiency.

Additionally, the use of single measure leads to ignoring any interactions, substitutions or tradeoffs among various performance measures. Each business operation has specific performance measures with certain compromises. For example, consider the tradeoff between total supply chain cost and supply chain response time, measured by the amount of time between an order placement and its delivery. Figure 2.1 illustrates alternate supply chain operations S1, S2, S3, and S, and the efficient frontier or tradeoff curve determined by them. A supply chain whose strategy is based on the efficient frontier is non-dominated in the sense that no alternate supply chain's performance is firmly better in both cost and response time. Through performance evaluation, the efficient frontier that represents the best practice is identified, and an inefficient strategy (e.g., point S) can be further improved (moved to the efficient frontier) with suggested directions for improvement (to S1, S2, S3 or other points along the frontier) (Zhu, 2009).

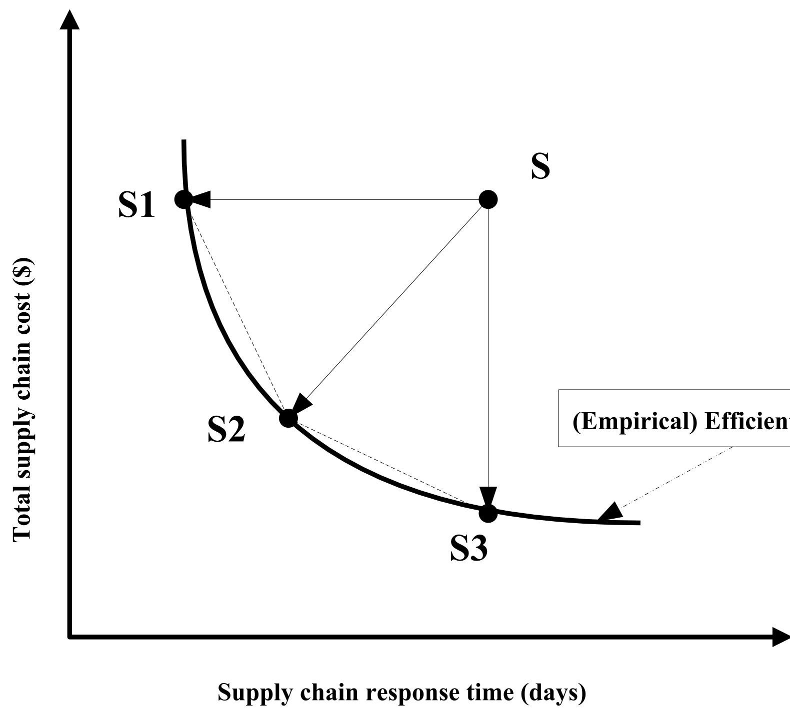


Figure 2.1 Efficient Frontier of Supply Chain Operations (adapted from Zhu, 2009)

Political, Economical, Social and Technological (PEST) analysis looks at elements that can affect an organization directly or indirectly (Panayiotou *et al.,* 2009).

In the current competitive environment, cost efficiencies and service targets are not the only strategic drivers for business development. A growing demand for triple-bottom-line (TBL) thinking (economic, environmental and social) is leading to sustainability considerations being incorporated into business and supply chain (SC) strategies, operations, and organizational cultures (Reefke & Trocchi, 2013).

2.2. Sustainability in Performance Management

The term "sustainable development" came into the picture in 1987, in a book published by the World Commission on Environment and Development (WCED) entitled "Our Common Future," which defined it as meeting "the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987).

Sustainability includes a focus on three primary dimensions for reaching overall performance: economic, environmental, and social. A majority of companies are implementing sustainability in order to grow, and to strengthen their image to improve competitiveness in the long term. It thus also leads to financial benefits (Arora, 2015).

The common element of corporate social responsibility (CSR), corporate social performance, stakeholder theory, the triple bottom line, and corporate sustainability is examining environmental and social issues, as well as financial goals in business (Hansen & Schaltegger, 2016). Sustainability performance measurement based on a system of indicators gives an organization data required to aid in the management, controlling, planning, and performance of the economic, environmental, and social activities they take on, in the short and long term (Medel-González *et al.,* 2016).

There is mounting pressure on corporations by various groups of stakeholders (e.g., governments, regulators, customers, local communities) to play a more active role in sustainable development, in line with new challenges. In response, a growing number of organizations are incorporating sustainability aspects into their business strategy and decision-making process to comply with strict laws and the expectations and concerns of several different stakeholders (Tsalis *et al.,* 2015).

Applying such practices, however, brings many challenges and requires innovative thinking and advanced decision making. One must take into account the development of technology, internal and external abilities and limitations, and social and environmental requirements and impacts (Reefke & Trocchi, 2013).

2.3. Tools for Sustainability Performance Measurement

In the perspective of sustainable development, international bodies such as the World Business Council for Sustainable Development (WBCSD), the Global Reporting Initiative (GRI), and the International Organization for Standardization (ISO), have started projects to encourage companies to address concerns with sustainability in their activities. These projects' outcomes are several sustainability frameworks whose goal is to aid companies in measuring corporate sustainability performance, integrating environmental and social aspects into their strategic goals, and communicating it to their important stakeholder groups (Tsalis *et al.,* 2015).

There also exist international guidelines and standards for incorporating sustainability management into businesses. A growing number of firms have embraced sustainability management related standards and guidelines including ISO 14000, Social Accountability (SA) 8000, ISO 26000, Accountability 1000, OECD Multinational Enterprises, Dow Jones Sustainability Index (DJSI) (2008), the United Nations Global Compact, and World Business Council for Sustainable Development (WBCSD) initiatives and especially the G3 (Global Reporting Initiative). The main obstacle for these guidelines and standards with regards to aiding firms in implementing various concepts of corporate sustainability management is that they are still only suggestions and recommendations on how to take corporate sustainability management (CSM) into account in the firm's operations and objectives (Lee & Farzipoor, 2012).

Multidimensional performance measurement and management models or performance measurement packages include: the Balanced Scorecard, the Performance Prism, and the dynamic multidimensional performance framework (Kaplan & Norton, 2005); (Neely, Adams, & Kennerley, 2002); (Maltz, Shenhar, & Reilly, 2003); (Hansen & Schaltegger, 2016).

The Balanced Scorecard (BSC) is one of the most widely used performance measurement and management tools. Although controversial, academics in the field of corporate sustainability have staunchly supported it (Figge *et al.,* 2002a); (Jensen, 2001); (Maltz *et al.,* 2003); (Hansen & Schaltegger, 2016).

The Performance Prism is a thinking aid which seeks to integrate five connected perspectives and offers a structure that permits executives to think through the answers to five fundamental aspects: stakeholder satisfaction, stakeholder contribution, strategies, processes, and capabilities (Neely *et al.,* 2002).

Maltz *et al.* (2003) developed a new performance model, called the dynamic multi-dimensional performance (DMP) framework. Based on this research, they recognized twelve potential baseline measures through five main success dimensions (financial, market, process, people, and future) that can be studied as applicable to diverse firms and firm types.

2.4. Sustainability Balanced Scorecard

2.4.1. Balanced Scorecard Definition

As first outlined by Kaplan and Norton in 1992, the Balanced Scorecard (BSC), is a strategic management tool to both operationalize and measure strategies of a company or its units (usually strategic business units), but may also be used as a comprehensive management system which cascades down from the administrative level, over business units and functions, to individuals, by means of incentive and compensation schemes (Kaplan & Norton, 2005); (Hansen & Schaltegger, 2016). The BSC's four perspectives may be summarized as (Figge *et al.,* 2002b):

- Financial perspective
- Customer perspective
- Internal process perspective
- Learning and growth perspective

Kaplan and Norton (1992, 1996) stated that the goal of the BSC is 'balancing' financial and non-financial, short-term and long-term, as well as qualitative and quantitative measures of success. In order to do this, it presents a set of strategic objectives defined by the business, which are each subsequently delegated to one of four performance perspectives (financial, customer, internal processes, learning and growth) ultimately leading to financial success, through chains of cause and effect (Hansen & Schaltegger, 2016). In this context, "balanced" means "balance between external measures for shareholders and customers, and internal measures of critical business processes, innovation, and learning and growth" (Möller & Schaltegger, 2005).

2.4.2. The Sustainability Balanced Scorecard (SBSC)

Both scholars and practitioners consider the BSC an appropriate tool to account for sustainability issues, because many environmental and social issues are non-financial and affect a company over the long term in particular. The SBSC is different in its architecture from the BSC in its explicit recognition of sustainability-related objectives and performance measures. There are two reasons that academics have highlighted the potential of the SBSC for incorporating conventional strategic management with corporate sustainability management: first, it lets management to address goals in all three dimensions of sustainability by integrating economic, environmental and social issues, whereas other methods only focus on one dimension. Second, the SBSC incorporates these three dimensions in a single integrated management system rather than many parallel systems (e.g., separate environmental, social and financial management systems). Researchers have developed extended scorecard designs on the basis of these factors, under the names of sustainability balanced scorecard, sustainability scorecard (SIGMA 2003) or responsive business scorecard (Figge *et al.,* 2002a); (Hansen & Schaltegger, 2016).

2.4.3. Integration of Environmental and Social Aspects in BSC

There are essentially three ways to incorporate environmental and social aspects into the BSC. Firstly, the existing four standard perspectives can incorporate new environmental or social factors. Secondly, it can be supplemented with new perspectives, to take into account different environmental and social aspects. Thirdly, a new scorecard can be formulated for a particular environmental and/or social aspect (Figge *et al.,* 2002b).

- Integration of environmental and social aspects in the four standard perspectives
- Introduction of an additional non-market perspective into the Balanced Scorecard
- Deduction of a derived environmental and social scorecard (Figge *et al.,* 2002b)

2.4.4. Process of formulating a Sustainability Balanced Scorecard

Few fundamental requirements must be met when creating a SBSC scorecard:

- The process must result in value-based management of environmental and social aspects.
- Environmental and social aspects must be incorporated into the general administration system of the company, so as to make sure of their value-based management.

- It must not be generic, but meet precisely the particular aspects and needs of the strategy, and the environmental and social aspects of the business unit. Thus, this process must make sure that the new SBSC is business-unit specific.
- The business unit's environmental and social aspects must be incorporated in correlation with their strategic relevance, included the consideration as to whether a new non-market perspective is necessary.

The process of formulating a sustainability-balanced scorecard is shown in Figure 2.2 (Figge *et al.,* 2002b).

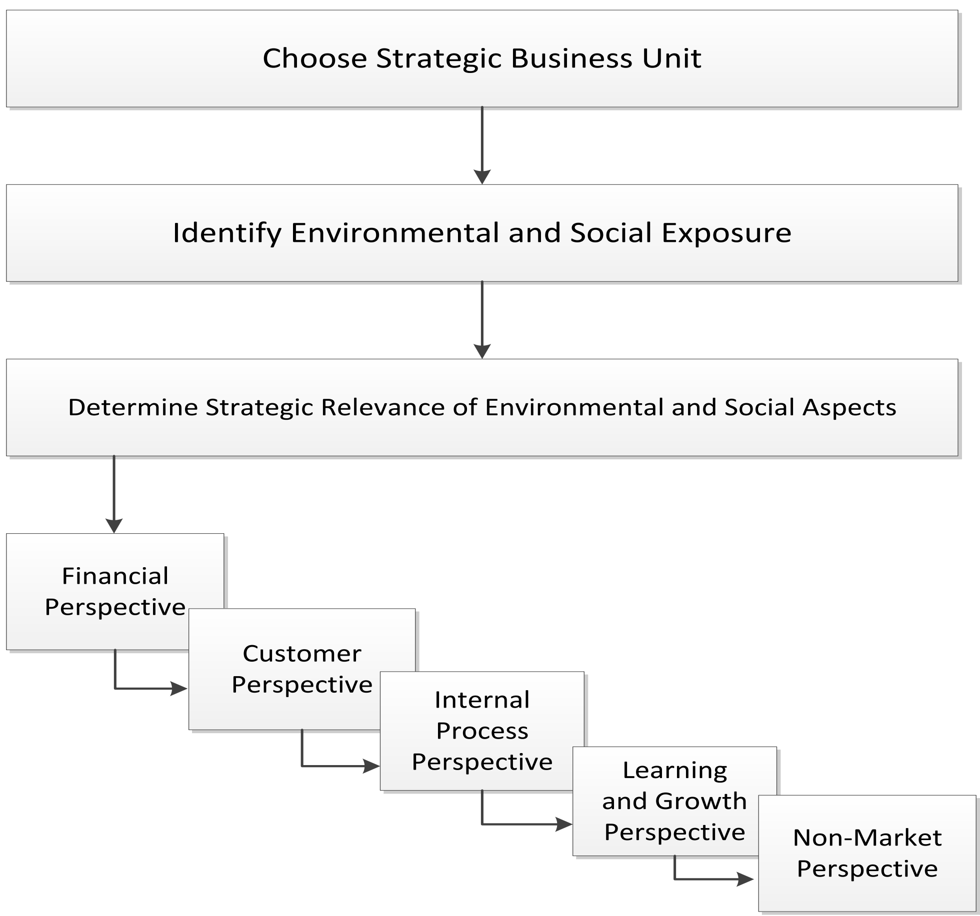


Figure 2.2 Process of Formulating Sustainability Balanced Scorecard (Figge et al. 2002)

Because societal issues comprise the framework of market operations with the financial community, customers, suppliers, and employees, the nonmarket perspective is shown as a basic layer in Figure 2.3 (Möller & Schaltegger, 2005).

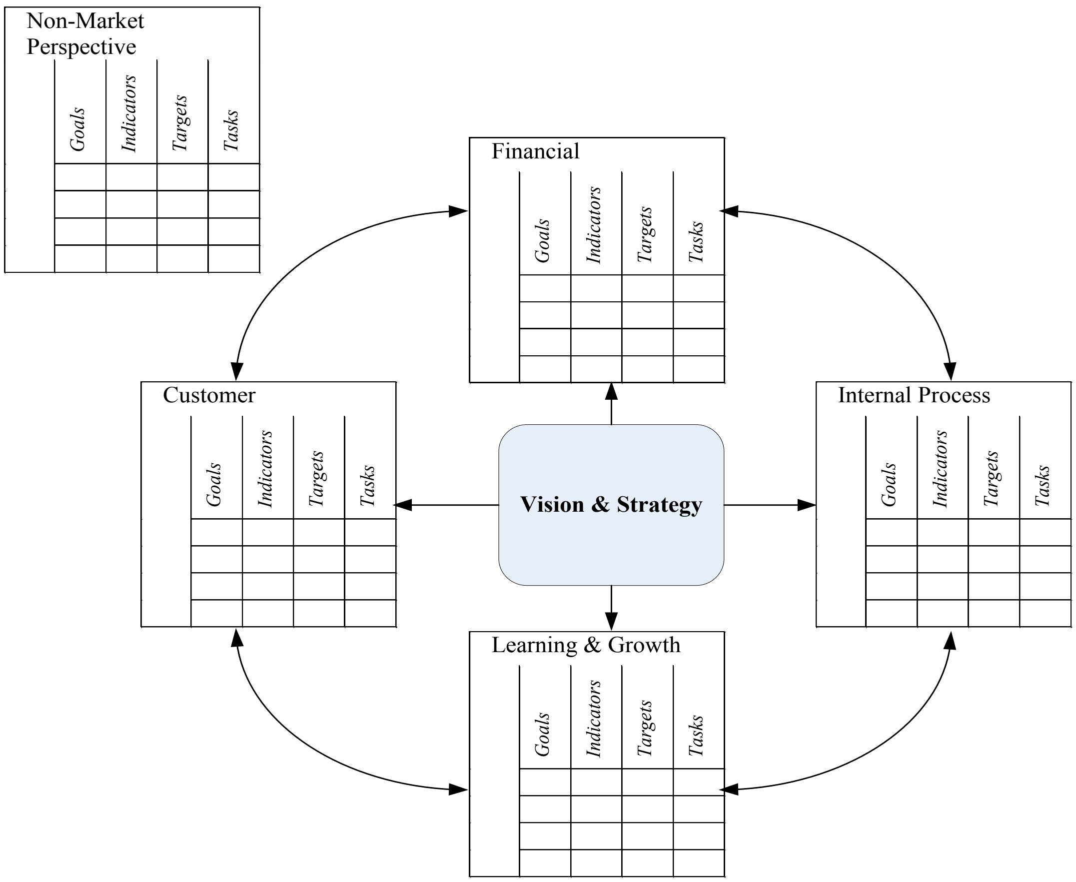


Figure 2.3 Balanced Scorecard Enhanced by a Nonmarket Perspective (Figge et al. 2002)

2.4.5. Types of Sustainable Balanced Scorecards

Corporations may see various gains from the application of a SBSC framework, which will differ depending on their function. Some of them strengthen the reporting process (see Table 2.1) (Tsalis *et al.,* 2015).

Studies	The Purpose of the SBSC Framework	The Framework's Articulation	Expected Contribution of the Proposed Framework
Sidiropoulos *et al.,* (2004)	Strategic Management	Five Perspectives	Improvements in marketing and in implementing of the sustainability strategy
Laurinkevičiūtė, Kinderytė, Stasiškienė, (2008)	Strategic Management	Four Perspectives	Improvements in the decision-making process
Yongvanich and Guthrie (2006)	Reporting Purpose	Three Basic Structures	Improvements in reporting of sustainable performance and in internal process
Thanaraksakul and Phruksaphanrat (2009)	Suppliers Evaluation	Five Perspectives	Better evaluation of potential suppliers
Moreo, DeMicco, and Xiong (2009)	Strategic Management	Five Perspectives	Improvements in understanding the role of environmental goals in corporate strategy
Panayiotou, Aravossis, and Moschou (2009)	Measurement of Sustainability Performance	Four Perspectives	Improvements in measurement of CSR performance
Hsu *et al.,* (2011)	Measurement of Sustainability Performance	Four Perspectives	Improvements in addressing and measurement of sustainable performance
Van der Woerd and Van den Brink (2004)	Strategic Management	Five Perspectives	Improvements in implementation of sustainable strategy
Tsai, Chou, and Hsu (2009)	SRI	Four Perspectives	Improvements in evaluation of SRI
Hubbard (2009)	Measurement of Sustainability Performance	Six Perspectives	Improvements in measurement and in reporting of corporate sustainable performance
Leon-Soriano, Muñoz-Torres, and Chalmeta-Rosaleñ (2010)	Strategic Management	Three Perspectives	Improvements in strategic planning and management
Wu and Liu (2010)	Performance Measurement	Five Perspectives	Better evaluation of ISO 14001 certified industries

Table 2.1 Proposed Frameworks Based on SBSC

2.5. Key Performance Indicators (KPIs)

2.5.1. KPI Definition

Key Performance Indicators (KPIs) help a company define and measure progress toward organizational goals and objectives. When a company has examined its mission and defined its objectives, it must next measure its progress towards those objectives. KPIs serve as a tool for such measurement.

KPIs help a company determine whether it is 'on track' –that it is working towards and attaining a beneficial outcome or improvement. In many circumstances, companies use KPIs in projects and to measure service delivery (APM).

2.5.2. How to set KPI's

In developing KPI's for a particular industry, one must start with knowledge of threats to sustainability that may apply to industries in all sectors. One must then identify one's own industry and shortlist the possible sustainability issues that are to be prioritized, and subsequently rank them. One must understand who the stakeholders in the company are, and how they may affected by possible sustainability issues. There must be a clear link between the top level goals and the KPI's, and they must be quantified, that is easily able to be reduced to numbers. The measurements must be uniform, which means specifically that a team should be assigned to conduct the measurements to avoid inconsistent results. Finally there must be some control over the corporate environment in order to achieve the KPI's. A machine operator, for example, should be able to make some changes by adjusting the setting of the machines. The strategic objectives provided by the KPI's can be used to discover opportunities, and areas in need of improvement. Gross profit margin and return on investment are examples of KPI's for financial performance (Arora, 2015).

A typical scorecard has twenty to twenty-five measures and the company may value a specific domain too highly or not enough. Scorecard targets and weights should be developed collaboratively between top management and line managers, in order to minimize bias and conflict and to increase congruence of the objectives (Houck *et al.,* 2012).

2.5.3. Six Big Challenges in Developing Key Performance Indicators

Substantial effort is needed to develop a high-quality set of performance indicators. Managers work with functional experts on a proposed set of measures, and then debate the prioritization of the different measures. Important challenges include:

1. If the company's strategy and key goals are unclear, the measures will tend to focus solely on financial outcomes.
2. If the measures rely on financial indicators too much, this gives an incomplete and unbalanced perspective on the state of the organization.
3. Measures which are seen as key in one area may not be considered important in other areas.
4. If compensation is tied to the targets for the performance indicators, this introduces considerable bias and conflict of interest into the process.
5. It is difficult to identify leading indicators.
6. It may be difficult or impossible to measure the identified measures precisely, and report on them, give the limitations of internal reporting systems (Reh, 2016).

Figure 2.4 shows the characteristic of KPIs (Shahin & Mahbod, 2007).

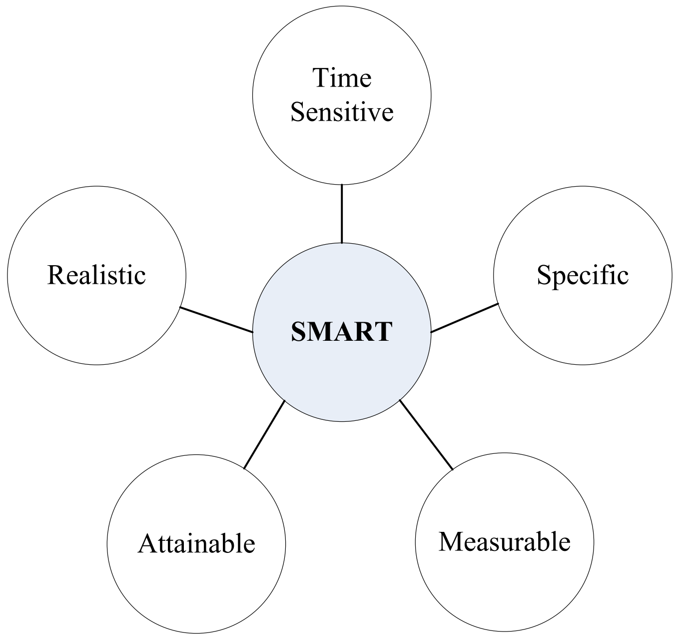


Figure 2.4 SMART Criteria for Developing KPIs

2.5.4. Sustainable KPI Initiatives

The tools currently available for supporting CSR management can be categorized into three groups:

- Tools derived from proposals by various governmental bodies in order to aid firms' awareness of CSR by defining principles of action relating to labor, environmental and human rights, and the struggle against corruption. An example of such a proposal is the Rio Declaration on Environment and Development
- Tools derived from standards which define guidelines for incorporating CSR into the administration of firms through a process of implementation, which may be or may not be auditable. Such standards include ISO 9001 and ISO 14001

- Tools derived from indicators used to create sustainability reports, such as GRI (Global Reporting Initiative) (Chalmeta & Palomero, 2011)

2.5.5. Sustainable KPI Frameworks

Many international initiatives have focused on sustainability indicators at different scales: global, national, regional, supply chain, company, factory, and process and product scope, with the goal of supplying the relevant information to various decision-making levels (Fantini, Palasciano, & Taisch, 2015).

There are many examples of developed sustainability indicators; both general and sector-specific (see Table 2.2). The primary concern with these indicator frameworks is that generally the spotlight is on the external reporting for stakeholders, rather than on internal information needed to make decisions and to revise or optimize for ecological innovation. Manufacturers in this situation need a standardized framework for the sustainable manufacturing environment, where they can easily evaluate and track their sustainability performance (Feng & Joung, 2009).

Indicator Set	Components	Reference
Global Report Initiative (GRI)	70 Indicators	http://www.globalreporting.org/ReportingFramework/ReportingFrameworkDownloads/
Dow Jones Sustainability Index (DJSI)	12 Criteria Based Single Indicator	http://www.sustainabilityindex.com/07_htmle/publications/guidebooks.html
2005 Environmental Sustainability Indicators	76 Building Blocks	http://www.yale.edu/esi/ESI2005.pdf
2006 Environment Performance Indicators	19 Indicators	http://sedac.ciesin.columbia.edu/es/epi/downloads/2006EPI_Report_Full.pdf
United Nations Committee on Sustainable Development Indicators	50 Indicators	http://www.un.org/esa/sustdev/natlinfo/indicators/guidelines.pdf
OECD Core Indicators	46 Indicators	http://www.oecdbookshop.org/oecd/display.asp?sf1=identifiers&st1=972000111E1
Indicator Database	409 Indicators	http://www.Sustainablemeasures.com
Ford Product Sustainability Index	8 Indicators	http://www.ford.com/doc/sr07-ford-psi.pdf
GM Metrics for Sustainable Manufacturing	46 Metrics	http://actionlearning.mit.edu/slab/files/slab_files/Projects/2009/GM,%20report.pdf
ISO 14031 Environmental Performance Evaluation	155 Example Indicators	http://www.iso.org/iso/iso_catalogue/catalogue_ics/catalogue_ics_browse.htm?ICS1=13&ICS2=20&ICS3=10
Wal-Mart Sustainability Product Index	15 Questions	http://walmartstores.com/download/3863.pdf
Environmental Indicators for European Union	60 Indicators	http://biogov.cpdr.ucl.ac.be/communication/papers/tepi99rp_EN105.pdf
Eco-Indicators 1999	3 Main Factors Based Single Indicator	http://www.pre.nl/eco-indicator99/ei99-reports.htm

Table 2.2 Various Sustainability Indicators & Metrics

2.5.6. Who's the best?

According to a recent GlobeScan/SustainAbility survey, CDP and DJSI are considered the most reliable reporting frameworks and are most widely used. GRESB, which applies exclusively to real estate owners, developers, and asset managers, is one of the fastest growing industry-specific standards. There is also GRI, which offers a prominent framework used for general corporate reporting. A newcomer, the Sustainability Accounting Standards Board (SASB), has arisen as the new standard for incorporating financial and non-financial reporting for publicly traded companies in the United States (see Table 2.3) (Measurabl, 2014).

STANDARD	FOCUS	SCORING	WHO REPORTS
CDP DRIVING SUSTAINABLE ECONOMIES	Primarily GHG emissions, but has grown to address water and forestry issues as well.	Companies receive two separate scores for Disclosure and Performance using a 100-point scale. CDP recognizes top scoring companies in the Carbon Disclosure Leadership Index (CDLI).	Public and private companies, cities, government agencies, NGOs, supply chains.
Dow Jones Sustainability Indexes	Industry-specific criteria considered material to investors. Equal balance of economic, social and environmental indicators.	Companies receive a total Sustainability Score is between 0 –100 and are ranked against peers; includes a Media and Stakeholder Analysis; those scoring within the top 10% are included in index.	The 2,500 largest companies in the S&P Global Broad Market Index.
Global Reporting Initiative™	Corporate social responsibility with an equal weight on environmental, social and governance factors. Heavy on stakeholder engagement to determine materiality.	Focus is on transparency so no true scoring methodology; new G.4 framework requires entity reporting to choose “Core” or “Complete” reporting.	Public and private companies, cities, government agencies, universities, hospitals, NGOs.
GRESB Global Real Estate Sustainability Benchmark	Environmental, social and governance performance in the global commercial real estate sector only. Includes asset- and entity-level disclosures.	Responses scored out of a possible 140.5 points distributed across two categories of data. Heavy weighting placed on implementation and asset level performance.	Commercial real estate owners, asset managers and developers.
SASB SUSTAINABILITY ACCOUNTING STANDARDS BOARD	US public companies only. Industry-specific issues deemed material to investors.	No scoring system. Instead, SASB is a standardized methodology for reporting sustainability performance through the Form 10-K.	No one yet – they’ve just released their first sector reporting guidelines.

Table 2.3 Top Five Sustainability Frameworks (According to GlobeScan/SustainAbility Survey)

2.5.6.1. Global Reporting Initiative (GRI)

The Global Reporting Initiative (GRI), also known as ecological footprint reporting, triple bottom line (TBL) reporting and corporate social responsibility (CSR) reporting, is a leading organization in the sustainability field. Its latest set of guidelines, named G4, is used by many corporations (Tsalis *et al.,* 2015).

About 90% of indicators used by all corporations are based on the GRI criteria, which demonstrates their influence in this field (Panayiotou *et al.,* 2009).

In July 2011, for example, over 1800 organizations in 60 countries were using the GRI guidelines (Lee & Farzipoor, 2012).

The GRI provides a useful pool of performance indicators concerning social responsibility, but it does not connect these indicators with strategy, nor does it link social responsibility behavior with the increase of the value of an organization. The integration of GRI indicators in the Balanced Scorecard method provides the advantages of both approaches (Panayiotou *et al.,* 2009).

2.5.6.2. Dow Jones Sustainability Index (DJSI)

The DJSI has tracked the financial performance of the leading sustainability-driven corporations since its launch in 1999. It is the first global index to track the financial performance of these corporations. It is in fact a family of indices, which contains a primary global index, the DJSI World, and others indices on the basis of geographic regions such as Asia-Pacific, Nordic, Europe, and North America (Das & Das, 2014).

2.6. MCDM Techniques

Worthwhile critiques of the BSC concept point out that there is no causal link between the measures from these four perspectives. In particular, there is no causal link between the measures with regard to sustainable development strategy, either (Tsai & Chou, 2009).

Although there are a multitude of potential gains for companies which adopt the SBSC, it has some shortcomings, resulting from the nature of the conventional BSC concept. Such deficiencies are essentially a reflection of the BSC's incapacity to account for the dynamic and complex aspects of a company's situation that influence the implementation of their strategies (Tsalis *et al.,* 2015).

Multi-criteria decision making (MCDM) methods address the decision-making process in the perspective of multiple goals. A decision-maker is required to select multiple criteria, quantifiable or non-quantifiable. The goals are usually in conflict and the solution is thus highly dependent on the preferences of the decision-maker and must be a compromise. Different groups of decision-makers will usually participate in the exercise. Each group has their own criteria and viewpoints, which must be resolved in a framework of mutual compromise and understanding. Applications of MCDM include areas such as integrated manufacturing systems, evaluations of technology investment, water and agriculture management, in addition to energy planning (Pohekar & Ramachandran, 2004).

2.6.1. Taxonomy of Multiple Criteria Decision- Making Methods

26 DM techniques are identified from three perspectives: (1) Multicriteria decision making (MCDM) techniques, (2) Mathematical programming (MP) techniques, and (3) Artificial

intelligence (AI) techniques (Chai, Liu, & Ngai, 2013). MCDM is the most well-known branch of decision making (Mardani *et al.,* 2015). We can classify them into four categories:

(1) Multiattribute utility methods such as AHP and ANP

(2) Outranking methods such as Elimination and Choice Expressing Reality (ELECTRE) and Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE)

(3) Compromise methods such as Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) and Multicriteria Optimization and Compromise Solution (VIKOR)

(4) Other MCDM techniques such as Simple Multiattribute Rating Technique (SMART) and Decision-Making Trial and Evaluation Laboratory (DEMATEL) and Data Envelopment Analysis (DEA) (Chai *et al.,* 2013).

A different integrated taxonomy was established by Hwang and Yoon (1981). This taxonomy distinguishes between Multiple-Objective Decision-Making (MODM) and Multiple-Attribute Decision-Making (MADM) methods, within the broader category of Multiple Criteria Decision-Aid MCDA. MODM methods are used in situations where there is a continuous spectrum or a large number of alternatives. MADM methods are used in cases of distinct, limited numbers of alternatives, characterized by conflicting criteria (see Figure 2.5), (Sadok *et al.,* 2008).

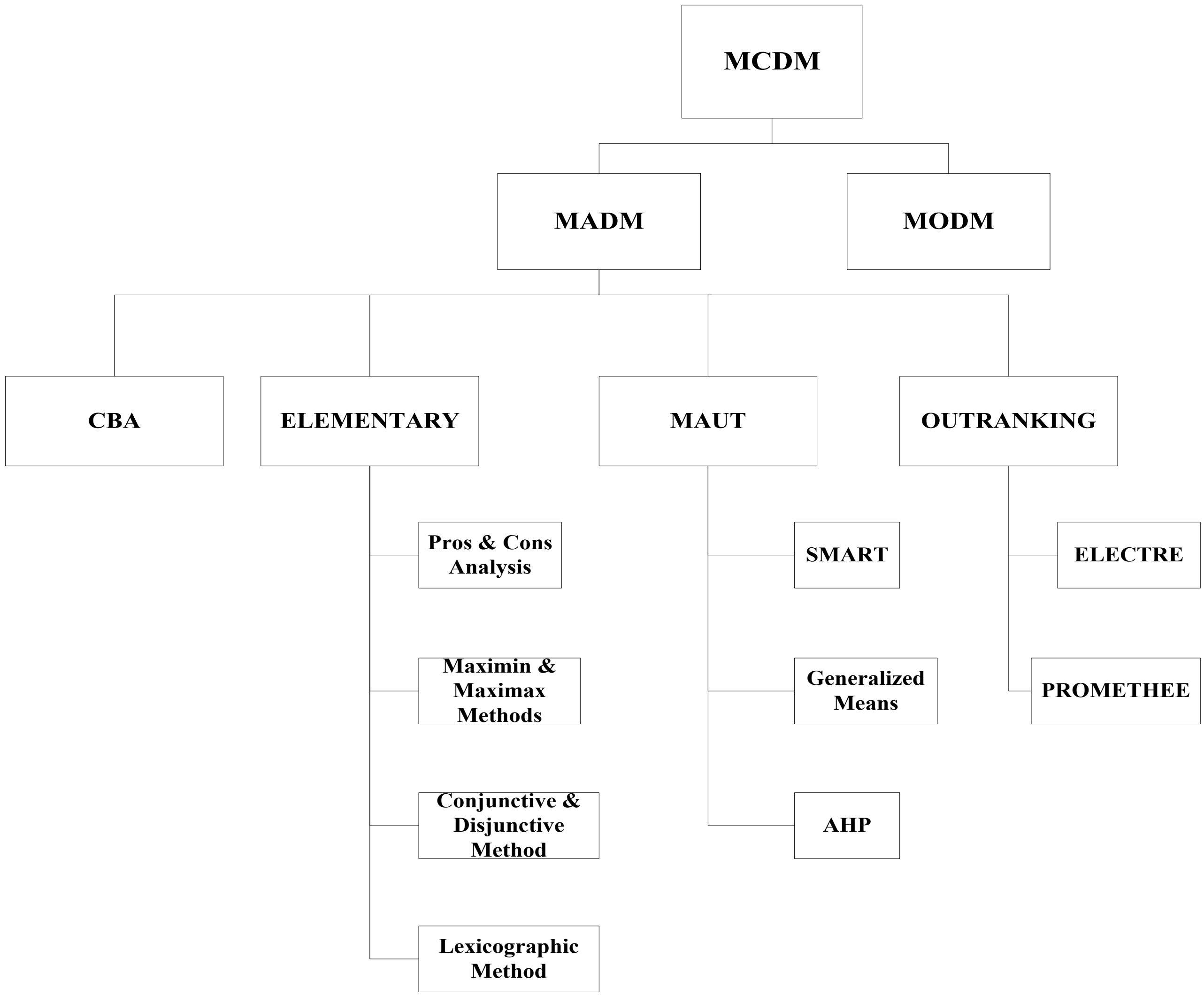


Figure 2.5 MCDM Hierarchy (Majdi, 2013)

Multi-Criteria Decision Aid (MCDA) or Multi-Criteria Decision Making (MCDM) methods have received a significant amount of attention from researchers and practitioners who are interested in evaluating and ranking alternatives across diverse industries (Behzadian *et al.,* 2012).

The distribution of a few of the major decision-making processes that appeared during the period 2008-12 is illustrated in table 2.4. Multi-attribute utility methods, including AHP and ANP, overshadow other techniques because of their effectiveness in ranking tasks and choices. TOPSIS and DEA remain significant in the construction of decision models. Considerable research attention is also being devoted to AI techniques, such as GA and GST (Chai *et al.*, 2013).

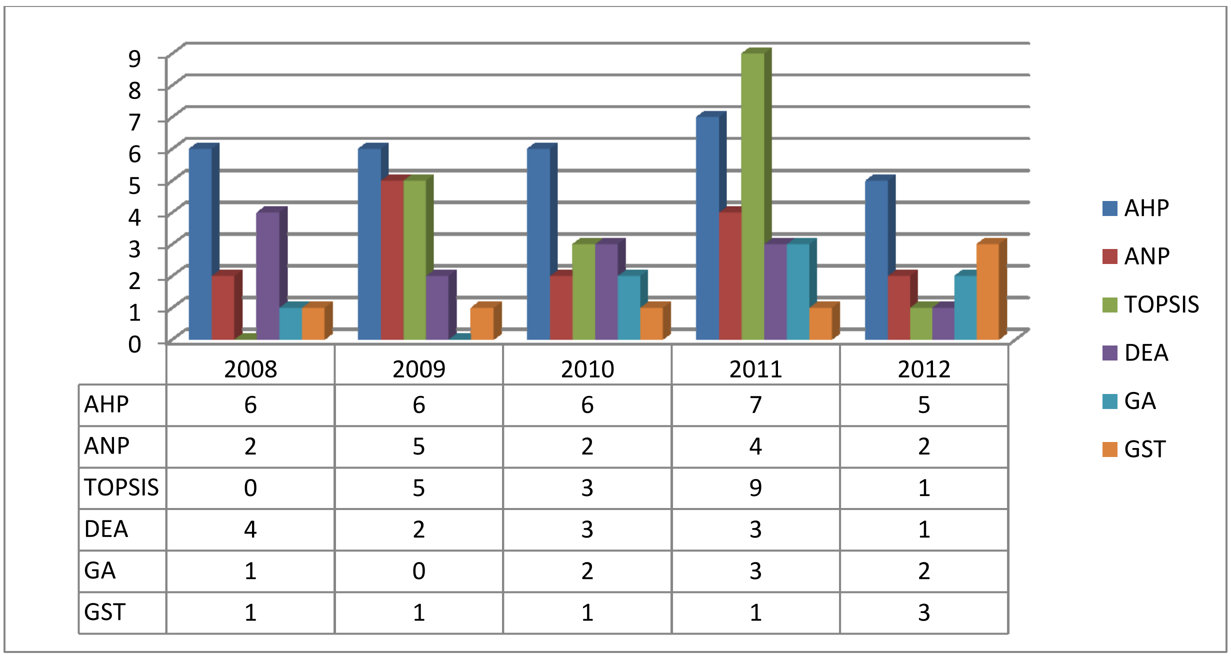


Table 2.4 Chronological Distribution of Some Major DM Techniques

Table 2.5 shows the application of various MCDM methods in the area of **Health, Safety and Environment Management.**

Author (s)	Specific area	Other techniques combined or compared	Group decision making
Aiello, Enea, Galante, and La Scalia (2009)	Selecting the most suitable extinguisher ozone-depleting substance	Fuzzy TOPSIS and AHP	
Berger (2006)	Generating depictions of the agricultural landscape for use in alternative future scenario modeling	–	
Chen, Blong, and Jacobson (2001)	Determining priority areas for a bushfire hazard reduction burning	Compromise programming and weighted linear combination	
Cheng, Chan, and Huang (2003)	Selecting landfill locations in the solid waste management problem	Inexact mixed integer linear programming, simple weighted addition, weighted	

		product, co-operative game theory, and complementary ELECTRE	
Ekmekçioglu, Kaya, and Kahraman (2010)	Selecting appropriate disposal methods and sites for municipal solid waste	Fuzzy TOPSIS and fuzzy AHP	
Grassi, Gamberini, Mora, and Rimini (2009)	Evaluating risk involved in hazardous activities of the production process of a well-known Italian sausage	Fuzzy TOPSIS	
Gumus (2009)	Selecting the right and most appropriate hazardous waste transportation firm	Fuzzy AHP and Delphi method Multi-objective	•
Han, Jia, and Tan (2003)	Selecting the best compromise solution for process environmental performance assessment	Multi-objective optimization, NSGA-II and AHP	
Huang, Zhang, Liu, and Sutherland (2011)	Environmentally conscious materials selection problem	Uncertainty analysis	
Kabak and Ruan (2010)	Nuclear safeguard evaluation for using nuclear programs for nuclear weapons purposes	SAW, Non-compensatory method, and fuzzy approach	
Krohling and Campanharo (2011)	Selecting the best alternatives to manage oil spill accidents in the sea in Brazil	Fuzzy TOPSIS	•
Li, Zhang, Zhang, and Suzuki (2009b)	Identifying the set of optimal parameters to design and optimize chemical processes based on green chemical principles	Multi-objective mixed integer non-linear mathematical model and NSGA-II	
Liu, Frazier, Kumar, Macgregor, and Blake (2006)	Assessing wetland conditions in the Clarence River Catchmen	–	
Olcer and Majumder (2006)	Selecting the set of counter-flooding tanks to achieve an optimal response to a flooding accident	–	
Onut and Soner (2008)	Solid waste transshipment site selection problem	Fuzzy AHP and fuzzy TOPSIS	
Rao and Baral (2011)	Evaluating available waste combinations and selecting the best waste combination	–	
Sadeghzadeh and Salehi (2011)	Ranking development alternatives based on eight technologies of accumulated fuel cells	–	
Shi, Xu, and Li (2009)	Evaluating and prioritizing the ecological revetment projects	Delphi-AHP method and fuzzy TOPSIS	
Simonovic and Verma (2008)	Waste water treatment planning problem	Fuzzy Pareto optimal solution set	
Sivapirakasam *et al.,* (2011)	Selecting process parameters to achieve green electrical discharge machining	Taguchi method and fuzzy TOPSIS	
Soltanmohammadi, Osanloo, and Aghajani Bazzazi (2010)	Determining a preference order of post-mining land uses	AHP	•
Tzeng, Lin, and Opricovic (2005)	Evaluating buses with alternative fuels for public transportation to improve environmental quality	AHP and VIKOR	•
Vahdani, Zandieh, and Tavakkoli-Moghaddam (2011b)	Determining appropriate fuel buses	Fuzzy TOPSIS	•
Wang, Fan, and Wang (2010)	Rating candidate aero engines for the aero engine health assessment problem	Fuzzy AHP and fuzzy preference programming	
Wang and Elhag (2006)	Optimal scheme of bridge structure maintenance problem	Fuzzy TOPSIS and nonlinear programming	
Yue (2011a)	Assessing air quality at the Asian Olympic Games in Guangzhou	Extended TOPSIS with interval numbers	•
Zavadskas and Antucheviciene (2006)	Ranking sustainable revitalization alternatives of derelict rural buildings in Lithuania	Fuzzy TOPSIS	
Zavadskas and Antucheviciene (2004)	Determining redevelopment priorities of buildings (sustainable development approach)	VIKOR	

Table 2.5Applied Papers in "Health, Safety and Environment Management"

Among the many MCDA/MCDM methods developed to address concrete decision problems, the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) continues to perform satisfactorily in various areas of application, because it has a comprehensible theoretical structure and can provide a precise model for making decisions. It is a well-known classical MCDA/MCDM method that has interested researchers and practitioners. Interest in the method globally has grown exponentially (Huang & Li, 2012).

Behzadian *et al.* (2012) conducted a survey of 269 papers and found that TOPSIS and its hybrid methods were used by 27.5% papers addressing the theme of Supply Chain Management and Logistics, 23% (Design, Engineering and Manufacturing Systems), 12.3% (Business and Marketing Management), 10.4% (Health, Safety and Environment Management), 8.9% (Human Resources Management), 5.2% (Energy Management), 2.6% (Chemical Engineering), 2.6% (Water Resources Management), and 7.4% (Other topics). Some application areas of TOPSIS based on work of Shih *et al.* (2007) are shown in table 2.6 (Mukherjee, 2014); (Kannan, Pokharel, & Kumar, 2009).

Application areas	No. of attributes	No. of alternatives	Proposed by
Company financial ratios comparison	4	7	Deng *et al.,* (2000)
Expatriate host country selection	Six major attributes & 25 sub-attributes	10	Chen and Tzeng (2004)
Facility location selection	5	4	Chu (2002)
Gear material selection	5	9	Milani *et al*., (2005)
High-speed transport system selection	15	3	Janic (2003)
Manufacturing plant location analysis	Five major attributes & 16 sub-attributes	5	Yoon and Hwang (1985)
Multiple response selection	2	18	Yang and Chou (2005)
Rapid prototyping-process selection	6	6	Byun and Lee (2005)
Robot selection	4	27	Parkan and Wu (1999)
Solid waste management	12	11	Cheng *et al*., (2002)
Water management	6	12	Srdjevic *et al*., (2004)

Table 2.6 Some Applications of TOPSIS Based on Work of Shih et al. (2007)

Table 2.7 displays the number and percentage distribution of techniques combined or compared with TOPSIS based on work of Behzadian *et al.* (2012).

Techniques combined or compared	N	%	Techniques combined or compared	N	%
Fuzzy set approach	139	52.2	Grey theory/analysis	7	2.6
Group decision-making approach	76	28.6	Delphi method	6	2.3
AHP	62	23.3	ELECTRE	5	1.9
Entropy method	20	7.5	Neural network	5	1.9
Multi-objective optimization	15	5.6	Compromise planning	4	1.5
Other mathematical programming	14	5.3	DEMATEL	4	1.5
Genetic algorithms	14	5.3	QFD	4	1.5
ANP	13	4.9	Principal component analysis (PCA)	4	1.5
Taguchi method	12	4.5	Nominal group technique	3	1.1
DEA	8	3	Signal-to-noise ratio	3	1.1
Simulation methods	8	3	PROMETHEE	3	0.8
VIKOR	7	2.6	MAUT	2	0.8
SAW	7	2.6	SERVQUAL	2	0.8

Table 2.7 Distribution of Techniques Combined or Compared with TOPSIS

2.6.2. DEA and BSC

DEA and BSC techniques have also been used by few researchers. Roodposhti *et al*. (2010), for example, introduce an analytical model for organizational performance evaluation based on DEA and BSC techniques. Ramanathan and Ramanathan (2011) suggest that BSC can be benefit by incorporating DEA. BSC with DEA has been used in the balanced performance evaluation of Health Authorities (HAs) in Great Britain (Arabzad *et al.,* 2013).

Chapter 3:

Solution Approach

3.1. Proposed Approach

Our solution approach involves four main steps:

1. Identification of KPIs for benchmarking sustainability performance of organizations considering the initiatives and frameworks related to sustainability studied in literature review (Chapter 2).

2. Measure and benchmark sustainability performance of organizations using the identified KPIs and TOPSIS technique.

3. Benchmark sustainability performance of organizations using the identified KPIs and DEA technique to identify efficient and inefficient units and determine improvement targets.

4. Compare the results obtained from steps 2 and 3 and generate recommendations.

These steps are explained in detail as follows:

3.2. KPIs Selection for Sustainability Measurement

To identify KPIs for sustainability measurement, we studied different initiatives and frameworks. United Nations Global Compact, World Business Council for Sustainable Development (WBCSD), Earth Charter and ISO are examples of such initiatives and GRI (Global Reporting

Initiative), DJSI (Dow Jones Sustainability Index), CK (Corporate Knights) and Sustainalytics are some examples of the frameworks which provide sustainability indicators.

We considered the strengths and limitations of each framework and selected the most appropriate one for our study.

1 - GRI (Global Reporting Initiative) is very famous and popular among researchers to use as a reference especially with its very professional categories: Economic, Environment and Social. The environmental indicators are generated based on series of sub-categories, including: Materials, Energy, Water, Biodiversity, Emissions, Affluent & Wastes, Products and Services, Compliance, Transport and Overalls. The social indicators falls into 4 sub categories namely Labor Practices, Human Rights, Society and Product Responsibility. Finally the economic indicators have 3 classifications. Each classification is further sub divided into a number of other indicators. number of indicators in each category is presented in Table 3.1 (Arora, 2015).

Category	*Subcategory*	*Number of Indicators*
Environment	Materials to Overall	30
Social	Labor Practices	14
	Human Rights	9
	Society	7
	Product Responsibility	9
Economic	Economic Performance	4
	Market Presence	3
	Indirect Economic Impacts	2

Table 3.1 GRI category, Subcategory & Indicators

2 - DJSI (Dow Jones Sustainability Index) is also very applicable and universal. There are different kinds of companies in all categories from all over the world.

The DJSI covers the top 10 percent of the biggest 2,500 companies in the Dow Jones Global Index that pursue economic, social, and environmental reporting (DJSIs, 2009) (Das & Das, 2014). However, access to the indicators, scores and possible rankings is not easy. DJSI although shows non-financial performance but helps to screen sustainability performances for investment purpose.

3 - CK (Corporate Knights) presents several different and very useful reports each year: Global 100, Future 40 and Future 50. Global 100 includes the best companies all over the world in sustainability performance based on just 12 indicators.

4 – Sustainalytics similar to GRI presents sustainability indicators in three major dimensions: Governance, Environment and Social. In each of the dimensions, several KPI (Key Performance Indicators) are considered. 21 KPIs in Governance, 14 KPIs in Social and 15 KPIs in Environment are used in this thesis (see Table 3.2).

S. Dimensions	***Governance***	***Social***	***Environment***
Sub-Dimensions No.	3	4	3
KPIs No.	21	14	15

Table 3.2 Sustainability Dimensions and Relates KPIs

Sustainalytics database not only includes very powerful indicators, but also provides the scores and rankings for companies. The access to database was also available through Concordia University Library.

With considering all above mentioned points, the preliminary data of this thesis is extracted from Sustainalytics database which follows and scores the sustainability performance of companies commonly in United States and Canada. We extracted the data only from the Canadian available industries to focus on Canadian market. A total of 50 KPIs from Sustainalytics database were considered in this thesis.

Table 3.3 shows the sustainability KPIs from Sustainalytics chosen for our study. There are three main dimensions: Governance, Social, and Environment.

Sustainability Scorecard		
Governance Score	**Social Score**	**Environment Score**
G.1.1 Bribery & Corruption Policy	S.1.1 Freedom of Association Policy	E.1.1 Environmental Policy
G.1.2 Whistleblower Programmes	S.1.2 Discrimination Policy	E.1.2 Environmental Management System
G.1.3 Global Compact Signatory	S.1.3 Diversity Programmes	E.1.3 EMS Certification
G.1.4 Tax Disclosure	S.1.4 Collective Bargaining Agreements	E.1.4 Environmental Fines & Penalties
G.1.5 Business Ethics Incidents	S.1.5 Employee Turnover Rate	E.1.5 CDP Participation
G.2.1 ESG Reporting Standards	S.1.6 Employee Fatalities	E.1.6 Scope of GHG Reporting
G.2.2 Verification of ESG Reporting	S.1.7 Employee Incidents	E.1.7 GHG Reduction Programme
G.2.3 Board Remuneration Disclosure	S.2.1 Scope of Social Supplier Standards	E.1.8 Renewable Energy Programmes
G.2.4 Board Biographies Disclosure	S.2.2 Supply Chain Monitoring	E.1.9 Carbon Intensity
G.2.5 ESG Governance	S.2.3 Social Supply Chain Incidents	E.1.10 Carbon Intensity Trend
G.2.6 ESG Performance Targets	S.3.2 QMS Certifications	E.1.11 Renewable Energy Use
G.2.7 Gender Diversity of Board	S.3.3 Customer Incidents	E.1.12 Operations Incidents
G.2.8 Separation of Chair & CEO	S.4.1 Activities in Sensitive Countries	E.2.1 Green Procurement Policy
G.2.9 Board Independence	S.4.3 Society & Community Incidents	E.2.2 Environmental Supply Chain Incidents
G.2.10 Audit Committee Independence		E.3.2 Product & Service Incidents
G.2.11 Non-Audit to Audit Fee Ratio		
G.2.12 Compensation Committee Independence		
G.2.13 Governance Incidents		
G.3.1 Political Involvement Policy		
G.3.2 Lobbying and Political Expenses		
G.3.4 Public Policy Incidents		

Table 3.3 Sustainability Scorecard (SSC)

The various KPIs or indicators belonging to these three dimensions are defined as follows:

G.1.1 Bribery & Corruption Policy: This indicator provides an assessment of the quality of the company's policy to combat bribery and corruption.

G.1.2 Whistleblower Programs: This indicator provides an assessment of the quality of the company's reporting mechanisms and structures to detect and address ethical misconduct.

G.1.3 Global Compact Signatory: This indicator denotes whether a company is a signatory to the United Nations Global Compact.

G.1.4 Tax Disclosure: This indicator provides an assessment of corporate transparency with regard to taxes paid and the possible use of tax shelters.

G.1.5 Business Ethics Incidents: This indicator analyses incident related to tax avoidance or evasion, bribery, corruption, money laundering or breach of intellectual property rights. For food companies, this indicator also covers animal welfare incidents.

G.2.1 ESG Reporting Standards: This indicator analyses the company's reporting on ESG matters and the extent to which it conforms to international standards as well as best practices.

G.2.2 Verification of ESG Reporting: This indicator provides an assessment of whether the company's sustainability report has been externally verified according to a report assurance standard.

G.2.3 Board Remuneration Disclosure: This indicator provides an assessment of the degree of disclosure of a company's directors' and CEO remuneration, including salaries, bonuses, long-term incentive schemes, benefits in kind, and pension contributions.

G.2.4 Board Biographies Disclosure: This indicator denotes whether the company discloses biographical details of directors including: name, age, position in the company, other positions held in listed companies or major institutions, and a broad outline of the past career.

G.2.5 ESG Governance: This indicator reviews how responsibilities for ESG issues are assigned within the company. It provides an assessment of whether there is explicit responsibility at the board level for ESG issues and/or whether there are committees dealing with ESG issues and how they are linked to the company board. Assigning clear, senior level responsibilities for ESG issues is considered an important factor for embedding ESG issues in a strategic manner in business operations.

G.2.6 ESG Performance Targets: This indicator provides an assessment of whether a part of executive remuneration is explicitly linked to sustainability performance targets, such as health and safety targets, environmental targets, etc.

G.2.7 Gender Diversity of Board: This indicator denotes the number of women on company boards. In case of two-tier structures, the composition of the Executive board as well as the Supervisory Board is considered.

G.2.8 Separation of Chair & CEO: This indicator provides an assessment on whether the positions of Chairman of the Board and CEO are combined or not.

G.2.9 Board Independence: This indicator provides an assessment of the independence of Supervisory Board members for two-tier boards, or, the independence of Board of Directors members for one-tier boards.

G.2.10 Audit Committee Independence: This indicator provides an assessment of the independence of Audit Committee members.

G.2.11 Non-Audit to Audit Fee Ratio: This indicator provides an assessment of the share of non-audit fees relative to audit-fees that the company paid to its auditor(s) in the most recent accounting year. Auditors' independence might be compromised by excessive levels of non-audit fees.

G.2.12 Compensation Committee Independence: This indicator provides an assessment of the independence of Compensation/Remuneration Committee members.

G.2.13 Governance Incidents: This indicator analyses incident related to board structures and independence, board disputes, disputed mergers, shareholder rights violations, excessive remuneration, and corporate failures due to mismanagement. For financial institutions, this indicator also captures resilience incidents, i.e. incidents that contribute to the financial institution's instability and increase the risks it poses to the financial system.

G.3.1 Political Involvement Policy: This indicator evaluates a company's policy on political involvement.

G.3.2 Lobbying and Political Expenses: This indicator provides an assessment of the total amount of political contributions or donations to political parties made by the company in the last three years.

G.3.4 Public Policy Incidents: This indicator analyses incident related to negative lobbying, political contributions in elections, lack of transparency over lobbying and political spending, electioneering in the workplace, and other forms of involvement in politics that create the perception that the company is trying to gain an unfair advantage.

S.1.1 Freedom of Association Policy: This indicator provides an assessment of the quality of a company's freedom of association and collective bargaining policy.

S.1.2 Discrimination Policy: This indicator provides an assessment of the quality of a company's policy to eliminate discrimination and ensure equal opportunity.

S.1.3 Diversity Programs: This indicator assesses the strength of the company's initiatives to increase the diversity of its workforce.

S.1.4 Collective Bargaining Agreements: This indicator provides an assessment of the extent that the company's employees are covered by collective bargaining agreements.

S.1.5 Employee Turnover Rate: This indicator provides an assessment of the extent to which a company is able to retain its employees.

S.1.6 Employee Fatalities: This indicator provides an assessment of whether the company is transparent about fatal accidents and of how the company's performance has developed over time.

S.1.7 Employee Incidents: This indicator analyses incident related to labor rights, labor relations, forced labor, child labor, and occupational health and safety.

S.2.1 Scope of Social Supplier Standards: This indicator provides a general assessment of whether the company has supply chain/contractors policies and the scope of social standards.

S.2.2 Supply Chain Monitoring: This indicator provides an assessment of whether the company has a supply chain monitoring system and/or whether there are other supply chain monitoring activities.

S.2.3 Social Supply Chain Incidents: This indicator measures incident related to discrimination, labor violations, customer mismanagement, anti-competitive practices, or health and safety among activities by a company's suppliers or contractors.

S.3.2 QMS Certifications: This attribute provides an assessment of the percentage of ISO 9000 certified (or similarly certified) sites.

S.3.3 Customer Incidents: This indicator analyses incident related to false or misleading advertising, breach of customers' data privacy, product quality and safety, and anti-competitive practices.

S.4.1 Activities in Sensitive Countries: This indicator provides an assessment of whether a company is present in sensitive countries. Currently, we only focus on Burma and Sudan.

S.4.3 Society & Community Incidents: This indicator analyses incident related to community relations, human rights violations, social impact of products and sanctions non-compliance.

E.1.1 Environmental Policy: This indicator provides an assessment of the quality of the company's commitment to protect the environment.

***E.1.2 Environmental Management System*:** This indicator provides an assessment of the quality and scope of a company's Environmental Management System.

***E.1.3 EMS Certification*:** This indicator provides an assessment of whether the company's Environmental Management System has received external certification (i.e. according to the ISO 14001 standard).

***E.1.4 Environmental Fines & Penalties*:** This indicator denotes whether the company has received environmental fines or non-monetary sanctions in the last three years.

***E.1.5 CDP Participation*:** This indicator provides an assessment of whether the company participates in the Carbon Disclose Project (CDP).

***E.1.6 Scope of GHG Reporting*:** This indicator focuses on corporate reporting on GHG emissions.

***E.1.7 GHG Reduction Program*:** This indicator assesses the strength of a company's initiatives to manage and reduce greenhouse gas (GHG) emissions associated with its own operations.

***E.1.8 Renewable Energy Programs*:** This indicator provides an assessment of whether the company has taken initiatives to increase the use of renewable energy.

E.1.9 Carbon Intensity: This indicator provides an assessment of the carbon intensity of a company relative to its peers. The carbon intensity of a company is calculated by dividing the annual CO2 eq emissions of a company by annual revenues (t.CO2eq./USD m. revenues). All the revenue data is taken from Capital IQ.

E.1.10 Carbon Intensity Trend: This indicator provides an assessment of the company's carbon intensity trend (t.CO2eq./USD m. revenues) over time. Currently, the 2012 data is compared to the average of the previous 3 years (2011-2009).

E.1.11 Renewable Energy Use: This indicator provides an assessment of the company's renewable energy consumption.

E.1.12 Operations Incidents: An analysis of incidents related to a company's failure to manage emissions, releases and waste, impacts on biodiversity or water, and its direct or indirect GHG emissions.

E.2.1 Green Procurement Policy: This indicator provides an assessment of the quality of a company’s green procurement’s commitment and initiatives.

E.2.2 Environmental Supply Chain Incidents: This indicator analyses incident related to environmental misconduct of a company's suppliers or contractors.

E.3.2 Product & Service Incidents: This indicator analyses incident related to products with negative direct or indirect, actual or potential impact on the environment.

3.3. Benchmarking Sustainability Performance

For benchmarking sustainability performance, two multicriteria decision making techniques namely TOPSIS and DEA are used. The reasons for selecting them are:

1. Both TOPSIS and DEA work with quantitative or numerical data.
2. TOPSIS generates rankings based on closeness to the ideal solution which is very powerful tool to evaluate the performance of alternatives from the ideal situation.

3. DEA is good for benchmarking, does not need expert judgment, shows efficiency and inefficiency for decision making units (or organizations) and provides recommendations for performance improvement of inefficient units.

These methods are described as follows.

3.4. TOPSIS Method

TOPSIS was introduced by Yoon (1980) and Hwang and Yoon (1981) for solving multiple criteria decision making (MCDM) problems. This methodology centers on the concept that the selected alternative solution should have the shortest Euclidian distance from the Positive Ideal Solution (PIS) and the farthest from the Negative Ideal Solution (NIS). The positive ideal solution is the solution that maximizes the benefit criteria and minimizes the cost criteria, while the negative ideal solution minimizes the benefit criteria and maximizes the cost criteria. The positive ideal solution is where all criteria are at the best possible value, and the negative ideal solution is where all criteria are at the worst possible value (Kuo, Hsu, & Chen, 2015) ; (Behzadian *et al.,* 2012).

For instance, PIS maximizes the profit and minimizes the used material, whereas the NIS maximizes the used material and minimizes the profit. This is based on the assumption that each criterion require to be maximized or minimized. It does not, however, take into account the relative importance of these distances (Mukherjee, 2014); (Kuo *et al.,* 2015).

TOPSIS method involves a series of successive steps described as follows (Srikrishna, Sreenivasulu, & Vani, 2014) ; (Huang & Li, 2012) ; (Behzadian *et al.,* 2012) :

Step 1: *Data Collection*

The first step of the TOPSIS method involves the construction of a Decision matrix (D).

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & & C_n \end{array} \\ \begin{bmatrix} X_{11} & X_{12} & \cdots & X_{1n} \\ X_{21} & X_{22} & \cdots & X_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ X_{m1} & X_{m2} & \cdots & X_{mn} \end{bmatrix} \end{array}$$

$i = 1, 2, \ldots, m; \qquad j = 1, 2, \ldots, n$ (3.1)

Where 'i' is the criterion index ($i = 1 \ldots m$); and 'j' is the alternative index ($j = 1 \ldots n$). The elements $C_1, C_2 \ldots, C_n$ refer to the alternative observations; while $A_1, A_2 \ldots,$ and A_m refer to the criteria. The elements of the matrix are related to the values of criteria i with respect to alternative j.

Step 2: *Data Normalization*

The Normalized Decision Matrix (NDM) contains the normalized values which represents the transformed values of the alternatives on a common scale. For example, different alternatives may be expressed in different units (e.g., km, kg, m3) and may have different nature (e.g., cost, revenue). Hence, it is important to bring their data to a common scale before the evaluation process through normalization. In literature, a variety of normalization methods have been proposed. For example, vector normalization, linear normalization, non-monotonic normalization (Shih *et al.,*2007). In our study, since, all the alternative values are on common scale (0-100) and have same nature (benefit type), normalization has less impact. To transform the alternative values to a score of (0-1), following normalization formula can been used.

$$NDM = R_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \qquad (3.2)$$

Step 3: *Determine the Weighted Score Values*

Not all of the selection criteria are of equal importance. The weighting decision matrix is constructed by multiplying each element of each column of the normalized decision matrix by its respective criteria weight.

$$V= V_{ij} = R_{ij} * W_j \qquad (3.3)$$

Step 4: *Determine the Positive and Negative Ideal Solution*

The positive ideal (*PIS* or A^+) and the negative ideal (*NIS* or A^-) solutions are defined according to the weighted decision matrix via equations (3.4) and (3.5) below

$$PIS = A^+ = \{V_1^+, V_2^+, \ldots, V_n^+\}, \text{ where: } V_j^+ = \{(max_i\ (V_{ij})\ if\ j \in J\ );\ (min_i\ V_{ij}\ if\ j \in J'\ )\} \qquad (3.4)$$

$$NIS = A^- = \{V_1^-, V_2^-, \ldots, V_n^-\}, \text{ where: } V_j^- = \{(min_i\ (V_{ij})\ if\ j \in J\ );\ (max_i\ V_{ij}\ if\ j \in J'\ )\} \qquad (3.5)$$

Where, J is associated with the beneficial attributes and J' is associated with the non-beneficial or cost attributes.

Step 5: *Calculate the Separation Measures Using the N-Dimensional Euclidean Distance*

Calculate the separation distance of each competitive alternative from ideal solution is given as

$$S^+ = \sqrt{\sum_{j=1}^{n} (V_j^+ - V_{ij})^2} \qquad i = 1, \ldots, m \qquad (3.6)$$

Similarly, the separation from the negative ideal solution is given as

$$S^- = \sqrt{\sum_{j=1}^{n}(V_j^- - V_{ij})^2} \qquad i = 1, \ldots, m \qquad (3.7)$$

Where, i = criterion index, j = alternative index.

Step 6: *Calculate the Relative Closeness of Each Observation to the Ideal Solution*

For each competitive alternative, the relative closeness of the potential location with respect to the ideal solution is computed using the following equation.

$$C_i = S_i^- / (S_i^+ + S_i^-) \ , \ 0 \leq C_i \leq 1 \qquad (3.8)$$

Note that $C_i = 0$ when $A_i = A^-$, and $C_i = 1$ when $A_i = A^+$.

Step 7: *Rank the Preference Order*

The higher the value of the relative closeness C_i, the higher the ranking order, and hence the better the performance of the alternative is. Ranking of C_i in descending order thus allows better comparison of relative performances (Srikrishna *et al.,* 2014) ; (Chang & Hsieh, 2014).

Shih *et al*. (2007) note that TOPSIS is straightforward and suitable for cases with an unlimited range of criteria and performance attributes, especially for use with objective or quantitative data. TOPSIS has many advantages:

(i) Explicit trade-offs and interactions among attributes are allowed for. Specifically, changes in one attribute can be compensated for in a direct or opposite manner by other attributes;

(ii) It uses logical thinking that corresponds with the rationale of human choice;

(iii) A scalar value is used which expresses the best and worst alternatives simultaneously;

(iv) As a comprehensible computation process, it can be easily programmed into a spreadsheet;

(v) The performance measures of all alternatives on attributes can be visualized on a polyhedron, at least for any two dimensions;

(vi) The preferential ranking of alternatives allows for a better comprehension of the similarities and differences between alternatives, unlike other MADM techniques (such as the ELECTRE) methods which just provide a ranking for each alternative (Huang & Li, 2012) ; (Govindan, Khodaverdi, & Jafarian, 2013).

Some of the limitations of TOPSIS are:

- It cannot weigh elicitation, requiring other techniques, such as the analytic hierarchy process (AHP) or analytic network process (ANP), to be used to addresses this limitation. The decision results may be influenced by normalization methods used in the decision matrix. Shih *et al*. (2007) described five normalization methods for decision makers, and stated corresponding suitable conditions for each (Huang & Li, 2012).
- Proximity degree is calculated, in the traditional TOPSIS method, by using Euclidean distance. However, in cases where results lead the evaluation scheme either close to the ideal solution or the negative ideal solution, the proximity degree cannot indicate relative merits of all the evaluation schemes, based on Euclidean distance (Gong, Hu, & Gao, 2013).
- Ranking alternatives by measuring relative distances is still open to question, and different measures have been used other than Euclidean distance. Examples are the least absolute value terms, Minkowskis metrics, and weighted Euclidean distance (Huang & Li, 2012).

- There are no recommendations for improvement suggested; only the distance from ideal solution is provided.

3.5. Data Envelopment Analysis (DEA) Method

DEA was first created by Charnes *et al.,* (1978) to assess non-profit and public-sector organizations. It was originally called the Charnes, Cooper and Rhoades (CCR) model. DEA has since become one of the most useful techniques for evaluating the performance of organizations such as business firms, government departments, hospitals etc. The decision maker is not required to define weights for each indicator. Instead, the weights are calculated from the data provided. DEA is also capable of distinguishing the benchmark entities on the basis of the efficiency score and finding the source and quantity of inefficiency.

The goal of DEA is to evaluate a given set of units, called decision-making units or DMUs, and determine the efficiency score of each one. A DMU is an entity whose performance is to be evaluated and which consumes inputs to produce outputs. These units can be the links in a supply chain, different organizations, or just different departments of one organization (Saleh, 2015).

DEA was created to measure the relative efficiency when no market prices are available, but because it has the ability to model multiple-input and multiple-output relationships without a priori assumption of an underlying functional form, the method has also been broadly used in other domains. Such domains include bank failure prediction, electric utilities evaluation, textile industry performance, steel industry productivity, highway maintenance efficiency, health care, software development, spatial efficiency, sports, and logistics systems, among others. Previous DEA studies furnish useful managerial information on enhancing performance. It is a particularly good tool for improving the productivity of companies in the service sector. It is also a common method for evaluating and selecting suppliers (Saleh, 2015).

Wong and Wong (2008) and Mahdiloo *et al*. (2011) list the following advantages of DEA:

1. It is an effective tool for evaluating the relative efficiency of DMUs in the presence of multiple performance measures.
2. It uses the concept of efficient frontier as a measure for performance evaluation. The efficient frontier used serves appropriately as an empirical standard of excellence.
3. It is able to deal with the complexity resulting from the absence of a common scale of measurement.
4. In DEA, there is no need to assume a priori the existence of a particular production function for weighting and aggregating inputs or outputs.
5. It does not need expert judgment, because the objectivity stemming from its weighting of variables during the optimization procedure allows the analysis to be free of subjective estimates (Lee & Farzipoor, 2012).

In addition to calculating the efficiency scores, DEA gives particular guidelines which are expressed as quantitative targets. These guidelines can be used to enhance efficiency, in a sustainability context (Galán-Martín *et al.,* 2016).

DEA has some shortcomings, despite its many advantages. One is that defining the input and output criteria may be confusing for the decision maker. Another is due to the subjective assignment of qualitative criteria. Thirdly, DEA determines the efficient decision making unit who generates more output while using less input, which raises the question of whether an efficient decision making unit can be considered an effective one (Ho, Xu, & Dey, 2010); (Saleh, 2015).

Even with its strengths, DEA has two main limitations in particular, that are critical when applied to sustainability assessment. The first is that it evaluates whether a unit is efficient or not, but does not make a distinction between units deemed efficient; that is, it does not rank them. All efficient units having the same efficiency score instead of being ranked, thus making it complicated to select a final alternative. The second is that the efficiency scores are quite sensitive to the quantity of inputs and outputs (in this context, sustainability indicators) and to the sample size. For sets of inputs and outputs with a large number of units, a circumstance that often applies to sustainability assessments, the absence of ranking leads to poor distinction of which of the many units can be considered efficient (Galán-Martín *et al.,* 2016).

Some researchers have used DEA in combination with multiple-criteria decision-making methodologies which require additional preferential information. Despite the numerous approaches developed to further distinguish among units however, no one methodology completely resolves to the ranking problem (Galán-Martín *et al.,* 2016).

DEA is a model that is peer-evaluated, rather than self-evaluated. Jahanshahloo *et al*. (2011) describe two main strengths of the cross-efficiency method: (1) it furnishes a unique order for the DMUs, and; (2) it removes unrealistic weight schemes without needing to elicit weight restrictions from experts in the application area (Lee & Farzipoor, 2012).

Two alternative approaches are available in DEA to determine the efficient frontier. One is input-oriented, and the other output-oriented.

The following DEA model is an input-oriented model where the inputs are minimized and the outputs are kept at their current levels.

$$\theta^* = \min \theta$$

subject to

$$\sum_{j=1}^{n} \lambda_j X_{ij} \leq \theta X_{i_o} \qquad i = 1,2,\ldots,m;$$

$$\sum_{j=1}^{n} \lambda_j Y_{rj} \geq Y_{r_o} \qquad r = 1,2,\ldots,s;$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j \geq 0 \qquad j = 1,2,\ldots,n; \qquad (3.9)$$

Where DMU_o represents one of the n DMUs under evaluation, and X_{i_o} and Y_{r_o} are the i^{th} input and r^{th} output for DMU_o respectively.

Since $\theta = 1$ is a feasible solution to (3.9), the optimal value to (3.9), $\theta^* \leq 1$. If $\theta^* = 1$, then the current input levels cannot be reduced (proportionally), indicating that DMU_o is on the frontier. Otherwise, if $\theta^* < 1$, then DMU_o is dominated by the frontier. θ^* represents the (input-oriented) efficiency score of DMU_o . (Zhu, 2009)

Figure 3.1 shows an input efficient frontier when outputs are fixed at their current levels (Walden & Kirkley, 2000). For example, the input in point (6,5) should be 3 for realizing output 5, because point (3,5) is located in the efficient frontier.

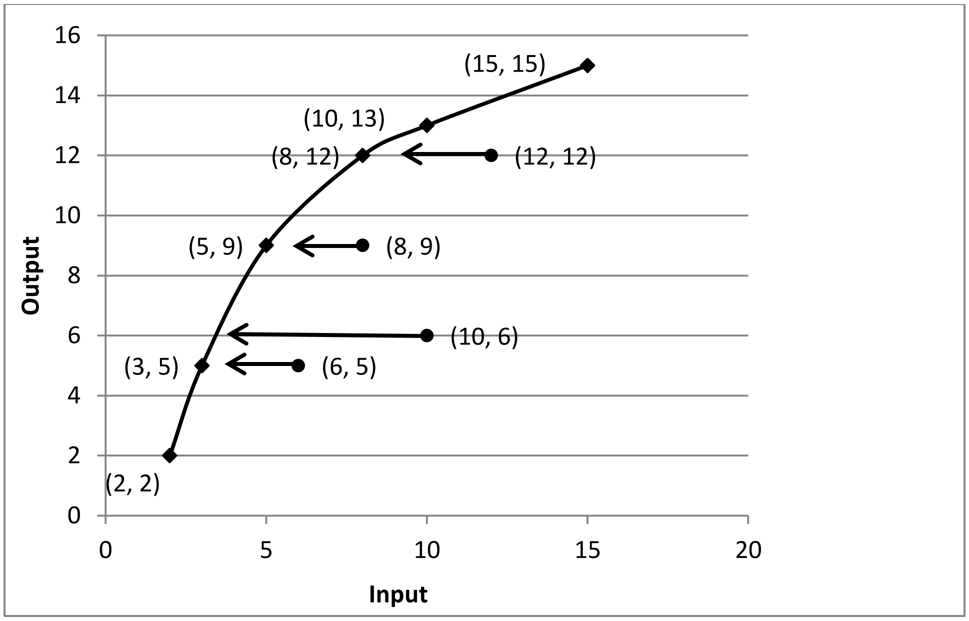


Figure 3.1 Input-Oriented DEA model

The following DEA model is an output-oriented model where the outputs are maximized and the inputs are kept at their current levels.

$$\boldsymbol{\theta^{*} = \max \theta}$$

subject to

$$\sum_{j=1}^{n} \lambda_j \, X_{ij} \leq X_{i_o} \qquad i = 1,2,\ldots,m;$$

$$\sum_{j=1}^{n} \lambda_j \, Y_{rj} \geq \theta \, Y_{r_o} \qquad r = 1,2,\ldots,s;$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j \geq 0 \qquad j = 1,2,\ldots,n; \qquad (3.10)$$

Where DMU_o represents one of the n DMUs under evaluation, and X_{io} and Y_{ro} are the i^{th} input and r^{th} output for DMU_o respectively.

Since $\theta = 1$ is a feasible solution to (3.10), the optimal value to (3.10), $\theta^* \geq 1$. If $\theta^* = 1$, then the current output levels cannot be increased (proportionally), indicating that DMU_o is on the frontier. Otherwise, if $\theta^* > 1$, then DMU_o is dominated by the frontier. θ^* represents the (output-oriented) efficiency score of DMU_o . (Zhu, 2009)

Similarly, we can obtain an output efficient frontier when inputs are fixed at their current levels (see Figure 3.2) (Walden & Kirkley, 2000). For example, the output in point (8,9) should be 12 for input 8, because point (8,12) is located in the efficient frontier.

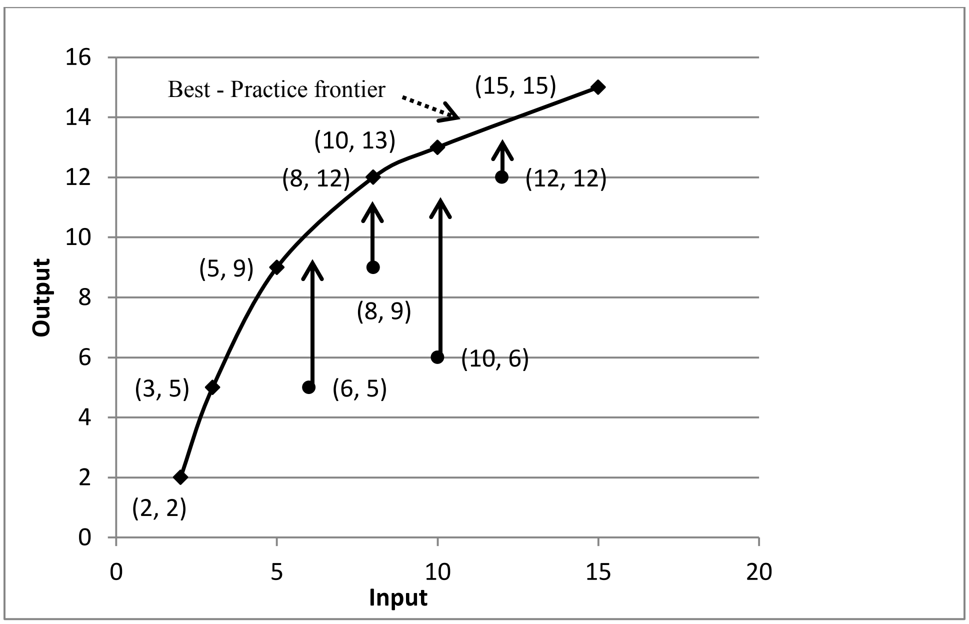


Figure 3.2 Output-Oriented DEA model

In Figure 3.3, DMUs 1, 2 and 3 are efficient.

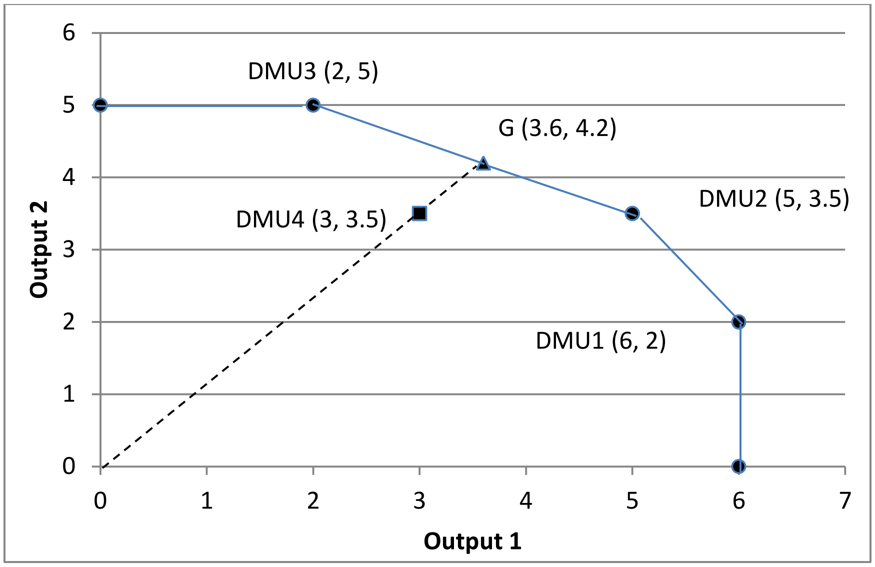


Figure 3.3 Output Efficient Frontier (Source: Zhu, 2009)

If we calculate model (3.10) for DMU_4,

Max θ

Subject to

$\lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 \leq 1$

$6\lambda_1 + 5\lambda_2 + 2\lambda_3 + 3\lambda_4 \geq 3\theta$

$2\lambda_1 + 3.5\lambda_2 + 5\lambda_3 + 3.5\lambda_4 \geq 3.5\theta$

$\lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 = 1$

$\lambda_1, \lambda_2, \lambda_3, \lambda_4 \geq 0$

We have G (3.6, 4.2) as an efficient performance with the same inputs.DMU_4 is inefficient and should growth its two output levels to G.

The interpretation of the envelopment model results can be summarized as:

i) If $\theta^* = 1$, then the DMU under evaluation is a frontier point. i.e., there are no other DMUs that are operating more efficiently than this DMU. Otherwise, if $\theta^* < 1$(input-oriented) or $\theta^* > 1$ (output-oriented), then the DMU under evaluation is inefficient. i.e., this DMU can either increase its output levels or decrease its input levels.

ii) The left-hand-side (LHS) of the envelopment models is usually called the “Reference Set”, and the right-hand-side (RHS) represents a specific DMU under evaluation. The non-zero optimal λj^* represent the benchmarks for a specific DMU under evaluation. The Reference Set provides coefficients (λj^*) to define the hypothetical efficient DMU. The Reference Set or the efficient target shows how inputs can be decreased and outputs increased to make the DMU under evaluation efficient (Zhu, 2009).

It is well known that large numbers of inputs and outputs compared to the number of DMUs may diminish the discriminatory power of DEA. A suggested “rule of thumb” is that the number of DMUs become at least twice the number of inputs and outputs combined (Golany & Roll, 1989).

$$\textbf{N (DMUs)} \geq \textbf{2*(Inputs + Outputs)}$$

Banker *et al*. (1989) on the other hand state that the number of DMUs should be at least three times the number of inputs and outputs combined.

$$\textbf{N (DMUs)} \geq \textbf{3*(Inputs + Outputs)}$$

However such a rule is neither imperative, nor does it have a statistical basis, but rather is often imposed for convenience. Otherwise, it is true that one loses discrimination power. It is not suggested, however, that such a rule is one that must be satisfied.

- There are situations where a significant number of DMUs are in fact efficient.
- In some cases the population size is small and does not permit one to add actual DMUs beyond a certain point.

However, if the user wishes to reduce the number or proportion of efficient DMUs, various DEA models can help; for example, weight restrictions may be useful in such cases (Cook *et al.,* 2013).

Our study is based on the output-oriented DEA model presented by Zhu (2009) which embodies the structure of the sustainability to explain and evaluate efficiency of individual observations. We use decision making units (DMUs) to represent business operations or processes. Each DMU contains a set of inputs and outputs, representing multiple performance measures.

The following rules are set for selecting the inputs and outputs:

- All inputs and outputs should have statistical data which is assumed to be equal or greater than zero.
- The variety of inputs, outputs and DMUs should be relevant to the study.
- Efficiency scores should reveal the following principles:
  - i. Smaller input amounts are preferable.
  - ii. Larger output amounts are preferable.
- The measurement units across the different inputs and outputs should not be the same.

Assume we have n different DMUs and each one has m input items and s output items.

Efficiency = Sum of weighted outputs / Sum of weighted inputs

This can be reformulated per CCR-DEA into the following linear program:

$$\textbf{Max } \boldsymbol{\theta_p}$$

$$\sum_j^n \mathrm{x}_{ij}\ \lambda_j \ \leq\ X_{\mathrm{ip}} \qquad \text{for all} \quad i = 1,2,\ldots,m;$$

subject to

$$\sum_j^n \mathrm{y}_{rj}\ \lambda_j \ \geq\ \theta\mathrm{p}\ y_{r\mathrm{p}} \qquad \text{for all} \quad r = 1,2,\ldots,s;$$

$$\sum_j^n \lambda_j \ =\ 1 \qquad\qquad (3.11)$$

Where:

θ_p is the efficiency score of DMU_p (the DMU under evaluation)

X_{ip} is the consumed amount of input i by DMU_p

y_{rp} is the produced amount of output r by DMU_p

λ_j is the computed weights associated with DMU_j determining whether it is a benchmark for DMU_p

x_{ij} is the consumed amount of input i by DMU_j

y_{rj} is the produced amount of output r by DMU_j

The above equations simply mean that the computed virtual DMU should satisfy two conditions:

(i) Consume the same or less input amount than DMU_p.

(ii) Produce the same or more output than DMU_p.

Moreover, we should note the following:

i. DMU_p is efficient when $\theta_p = 1$.

ii. DMU_p is inefficient when $\theta_p > 1$.

iii. Efficiency cannot be lesser than 1. (Zhu, 2009) ; (Saleh, 2015)

Consider a set of n observations on the DMUs. Each observation, DMU_j ($j = 1, \ldots, n$), uses m inputs x_{ij} ($i = 1, 2, \ldots, m$) to produce s outputs y_{rj} ($r = 1, 2, \ldots, s$).

The (empirical) efficient frontier or best-practice frontier is determined by these n observations. The following two properties ensure that we can develop a piecewise linear approximation to the efficient frontier and the area dominated by the frontier.

Property 1.1 Convexity. $\sum_{j=1}^{n} x_{ij}\ \lambda_j$ $(i = 1,2,...,m)$ and $\sum_{j=1}^{n} y_{rj}\ \lambda_j$ (r = 1,2,…,s) are possible inputs and outputs achievable by the DMU_j, where λ_j $(j = 1, \ldots, n)$ are nonnegative scalars such that $\sum_{j=1}^{n} \lambda_j = 1$.

Property 1.2 Inefficiency. More y_{rj} can be obtained by using the same x_{ij}, where $\hat{y}_{rj} \geq y_{rj}$ (i.e., more outputs can be produced with the same inputs); The same x_{ij} can be used to obtain $\hat{y}_{rj}$, where $\hat{y}_{rj} \geq y_{rj}$ (i.e., the same inputs can be used to produce more outputs). (Zhu, 2009)

3.6. TOPSIS and DEA Results Comparison

Our methodology is based on using the database of Sustainalytics 2016 in two major sectors, service and manufacturing. We will use 8 different categories in each sector. In each category, three companies will be assessed. The best and two worst cases in each category will be selected. In the first step we will implement the TOPSIS method and generate organization ranking. This concept will show the gap between the performance of each company and the best one based on the performance of all companies in the sample.

In the second step we will implement the DEA method. The results will show the ranking, efficient and inefficient companies, and recommendations or improvement targets for the inefficient companies.

Finally, we will compare the ranking results of these two methods with the original one to find any possible matchings or correlations. Although the concepts of these three approaches are different, yet we will attempt to interpret the results in the best way.

Chapter 4:

Numerical Application

4.1. Introduction

We considered two major sectors (manufacturing and service) for our study, with each having 24 companies organized in 8 categories. The manufacturing categories comprise of Oil & Gas producers, Aerospace & Defense, Auto components, Transportation, Chemicals, Diversified metals, Paper & Forestry, and Precious metals. The service categories comprise of Banks, Diversified financials, Insurance, Media, Telecommunication services, Commercial services, Energy services, and Real estate. The sustainability performance of 24 different companies in each sector was benchmarked against each other to determine their relative scoring. The organization with the highest score (Total ESG Score) was considered to be performing best in terms of sustainability. The criteria used for measuring the sustainability performance are Governance, Social and Environment. In each of the dimensions, several KPI (Key Performance Indicators) are considered. There are 21 KPIs in Governance, 14 KPIs in Social and 15 KPIs in Environment dimension. A total of 50 KPIs were used for evaluation. Table 4.1 summarizes this information.

S. Dimensions	**Governance**	**Social**	**Environment**
Sub-Dimensions No.	3	4	3
KPIs No.	21	14	15

Table 4.1 Sustainability Dimensions and relates KPIs

In the original Sustainalytics database, there are more than 50 KPIs, however we have limited our study to only 50 for multiple reasons. Firstly, we intend to integrate the whole study by using exactly the same KPIs for all companies. Some KPIs were not applicable to all companies.

Secondly, many KPIs had non-numerical values, hence they were ignored. Lastly, some of them did not have value and were shown as “No data” in the database. We considered zero value for them to give them numerical value to unify the study.

These little changes also affect the cumulative values of each company when compared to the original dataset ranking.

To see the list of all Sustainalytics KPIs, please visit appendix A.

4.2. TOPSIS

4.2.1. Weight Allocation

For TOPSIS application, the raw data of KPIs should be weighted. In Sustainalytics database, this weight allocation is already done. Each KPI has been given a raw score and weight. The raw score is given on a scale of 100 by research analysts as follows (see Table 4.2).

Description	Raw Score
The company has a very strong programme	100
The company has a strong programme	75
The company has an adequate programme	50
The company has a weak programme	25
The company does not disclose a programme	0

Table 4.2Raw Score Concept for KPIs

Each key indicator has individual weight. Weights are determined by their relevance to the key ESG (Environment, Social and Governance) issues they track. This would mean that the more relevant an indicator is, the higher its weight is. Weights are specific to the peer group. A higher weight is the indicator that it is more relevant to the industry.

These weights are multiplied with the raw score to form the weighted score. Table 4.3 shows a summary of process.

G.1.1 Bribery & Corruption Policy-Raw Score	G.1.1 Bribery & Corruption Policy-Weight	G.1.1 Bribery & Corruption Policy-Weighted Score
100	0.0100	1.0000

Table 4.3 Summary of Weighted Score Process

Table 4.4 presents the weighted score KPI values for Banks category (service sector). In appendix B the weighted score values of KPIs in services sector (three categories) is presented as an embedded excel file.

4.2.2. Determine the Positive and Negative Ideal Solutions

The Positive Ideal (A^+) and the Negative Ideal (A^-) Solutions are defined according to the weighted decision matrix via equations (3.4) and (3.5).

As the database is based on KPIs in sustainability area and considering the definition of KPIs in this field, all the KPIs belong to beneficial attributes. There is no cost attribute. The results of positive and negative ideal solutions of Banks category using equations (3.4-3.5) is presented in Table 4.4.

			Banks				
			Co. 1	Co. 2	Co. 3	*PIS*	*NIS*
Governance	Business Ethics	G.1.1	0.4600	0.4600	0.4800	0.48	0.46
		G.1.2	1.2300	1.2300	1.2300	1.23	1.23
		G.1.3	0.0000	0.0000	0.0000	0	0
		G.1.4	0.0000	0.0000	0.0000	0	0
		G.1.5	6.4000	4.0000	8.0000	8	4
	Corporate Governance	G.2.1	0.7200	0.4800	0.0000	0.72	0
		G.2.2	0.4800	0.4800	0.0000	0.48	0
		G.2.3	0.2100	0.2100	0.0000	0.21	0
		G.2.4	0.2100	0.2100	0.0000	0.21	0
		G.2.5	0.9600	0.9600	0.0000	0.96	0
		G.2.6	0.9600	0.2400	0.0000	0.96	0
		G.2.7	0.9600	0.9600	0.0000	0.96	0
		G.2.8	0.4600	0.4600	2.2100	2.21	0.46
		G.2.9	0.9600	0.9600	2.7100	2.71	0.96
		G.2.10	0.2100	0.2100	0.0000	0.21	0
		G.2.11	0.2100	0.2100	0.0000	0.21	0
		G.2.12	0.2100	0.2100	0.0000	0.21	0
		G.2.13	4.2100	3.3680	4.2100	4.21	3.368
	Public Policy	G.3.1	0.1775	0.1775	0.0000	0.1775	0
		G.3.2	0.0000	0.0000	0.0000	0	0
		G.3.4	1.4600	1.4600	2.9600	2.96	1.46
Social	Employees	S.1.1	0.2825	0.2260	0.0000	0.2825	0
		S.1.2	1.0650	1.0650	0.9375	1.065	0.9375
		S.1.3	2.1300	2.1300	0.0000	2.13	0
		S.1.4	0.2825	0.2825	0.0000	0.2825	0
		S.1.5	0.0000	0.0000	0.0000	0	0
		S.1.6	0.0000	0.0000	0.0000	0	0
		S.1.7	4.9500	4.9500	6.0000	6	4.95
	Social Supply Chain	S.2.1	0.5650	0.2825	0.0000	0.565	0
		S.2.2	1.6300	1.6300	0.0000	1.63	0
		S.2.3	1.5000	1.5000	1.5000	1.5	1.5
	Customers	S.3.2	0.0000	0.0000	0.0000	0	0
		S.3.3	4.7920	4.7920	4.7920	4.792	4.792
	Communi ty &	S.4.1	0.0100	0.0100	0.0100	0.01	0.01

		S.4.3	3.2000	3.2000	4.0000	4	3.2
Environment	Operations Score	E.1.1	0.5000	0.5000	0.3750	0.5	0.375
		E.1.2	1.0000	0.8000	0.4000	1	0.4
		E.1.3	0.0000	0.0000	0.0000	0	0
		E.1.4	0.5000	0.5000	0.0000	0.5	0
		E.1.5	0.5000	0.5000	0.0000	0.5	0
		E.1.6	0.2500	0.2500	0.0000	0.25	0
		E.1.7	0.5000	0.5000	0.3750	0.5	0.375
		E.1.8	0.5000	0.1250	0.0000	0.5	0
		E.1.9	0.5000	0.5000	0.0000	0.5	0
		E.1.10	0.1250	0.2500	0.0000	0.25	0
		E.1.11	0.5000	0.0000	0.0000	0.5	0
		E.1.12	3.5000	3.5000	3.5000	3.5	3.5
	Environmental Supply Chain	E.2.1	1.2000	1.2000	0.0000	1.2	0
		E.2.2	1.0000	1.0000	1.0000	1	1
	Products & Services	E.3.2	4.0000	4.0000	5.0000	5	4

Table 4.4 Weighted Score KPI, PIS & NIS Values in Banks category (Service sector)

4.2.3. Calculate the Separation Measures Using the n-Dimensional Euclidean Distance

Calculate the separation distance of each competitive alternative from Ideal Solution is given as

$$S^{+} = \sqrt{\sum_{j=1}^{n}(V_j^{+} - V_{ij})^2} \qquad i = 1, \ldots, m$$

Similarly, the separation from the Negative Ideal Solution is given as

$$S^{-} = \sqrt{\sum_{j=1}^{n}(V_j^{-} - V_{ij})^2} \qquad i = 1, \ldots, m$$

Where, i = criterion index, j = alternative index.

The result of S^{+}, S^{-} of Banks category is presented in Table 4.5.

	Banks		
	Co. 1	Co. 2	Co. 3
S+	3.700476	5.377405	3.828936
S-	4.591605	3.543477	5.275117

Table 4.5 Separation Distances in Banks Example

4.2.4. Measure the Relative Closeness of Each Location to the Ideal Solutions

For each competitive alternative the Relative Closeness (C_i) of the potential location with respect to the Ideal Solutions (A^+) is computed.

$$C_i = S_i^- / (S_i^+ + S_i^-) \ , \ 0 \leq C_i \leq 1$$

After calculating the S^+ and S^- for service sector and manufacturing sector, the closeness of each industry to the Ideal Solutions C_i is calculated.

4.2.5. Ranking the Preference Order

According to the value of C_i the higher the value of the relative closeness, the higher the ranking order and hence the better the performance of the alternative in sustainability area. Ranking of the preference in descending order thus allows relatively better performances to be compared.

Therefore the maximum value of Ci is the best one and receives first rank.

As an example, the result of S^+, S^- , C_i and ranking of Banks category is presented in Table 4.6.

	Banks		
	Co. 1	Co. 2	Co. 3
S+	3.700476	5.377405	3.828936
S-	4.591605	3.543477	5.275117
C_i	0.553734	0.397211	0.579425
C_i ranking	2	3	1

Table 4.6 Separation Distances, Relative Closeness and Ranking Results in Banks Category Example

4.2.5.1. Ranking the Service Sector Organizations

Table 4.7 shows TOPSIS calculations for service industries and the resulting rankings. It can be seen that most of the industries are so far from the Ideal Solutions. Only Co. 7.1 in Energy S. presents a good performance with Relative Closeness more than 0.5; or 0.5206 value which receives the first rank. It means there is opportunity to increase the sustainability performance of service industries.

The ranking of each organization (observation) includes 50 criteria and depends on their scores with respect to the maximum and minimum values for that criterion (extracted from 24 observations). For example, Operation Incidents values for ranking 1 and 24 are 12 and 3.5 respectively which also represent maximum and minimum of this criterion. The same pattern can be observed for other KPIs such as CDP Participation criterion. The performance of each observation can be justified by comparing its outputs with maximum and minimum of each criterion.

No.	Sector	Company No.	S^+	S^-	Relative Closeness Index(Ci)	TOPSIS Ranking
1	Banks (1)	Co. 1.1	14.0698	6.42921	0.31364	18
2		Co. 1.2	14.67017	5.36732	0.26786	24
3		Co. 1.3	14.18167	7.81761	0.35536	9
4	Diversified Financials (2)	Co. 2.1	13.83975	8.55108	0.3819	7
5		Co. 2.2	14.70439	7.33937	0.33295	15
6		Co. 2.3	15.10479	7.08166	0.31919	17
7	Insurance (3)	Co. 3.1	14.05299	7.54236	0.34926	11
8		Co. 3.2	14.43175	6.98247	0.32607	16
9		Co. 3.3	15.18127	6.15005	0.28831	22
10	Media (4)	Co. 4.1	13.22179	9.21815	0.41079	6
11		Co. 4.2	14.78853	8.07903	0.3533	10
12		Co. 4.3	14.9603	7.77147	0.34188	13
13	Telecommunication S. (5)	Co. 5.1	12.8304	6.6673	0.34195	12
14		Co. 5.2	13.39163	5.88509	0.3053	20
15		Co. 5.3	13.40923	6.0832	0.31208	19
16	Commercial S. (6)	Co. 6.1	11.9106	9.31288	0.4388	3
17		Co. 6.2	12.24649	9.15018	0.42764	5
18		Co. 6.3	13.49059	7.47141	0.35643	8
19	Energy S. (7)	Co. 7.1	10.95774	11.89935	0.5206	1
20		Co. 7.2	12.73807	10.31828	0.44752	2
21		Co. 7.3	12.9315	9.87669	0.43303	4
22	Real Estate (8)	Co. 8.1	13.87218	7.16229	0.3405	14
23		Co. 8.2	14.76825	6.05354	0.29073	21
24		Co. 8.3	14.86262	5.98104	0.28695	23

Table 4.7 TOPSIS Calculations and the Resulted Rankings for Service Sector Companies

The results for service sector are presented in Figure 4.1.

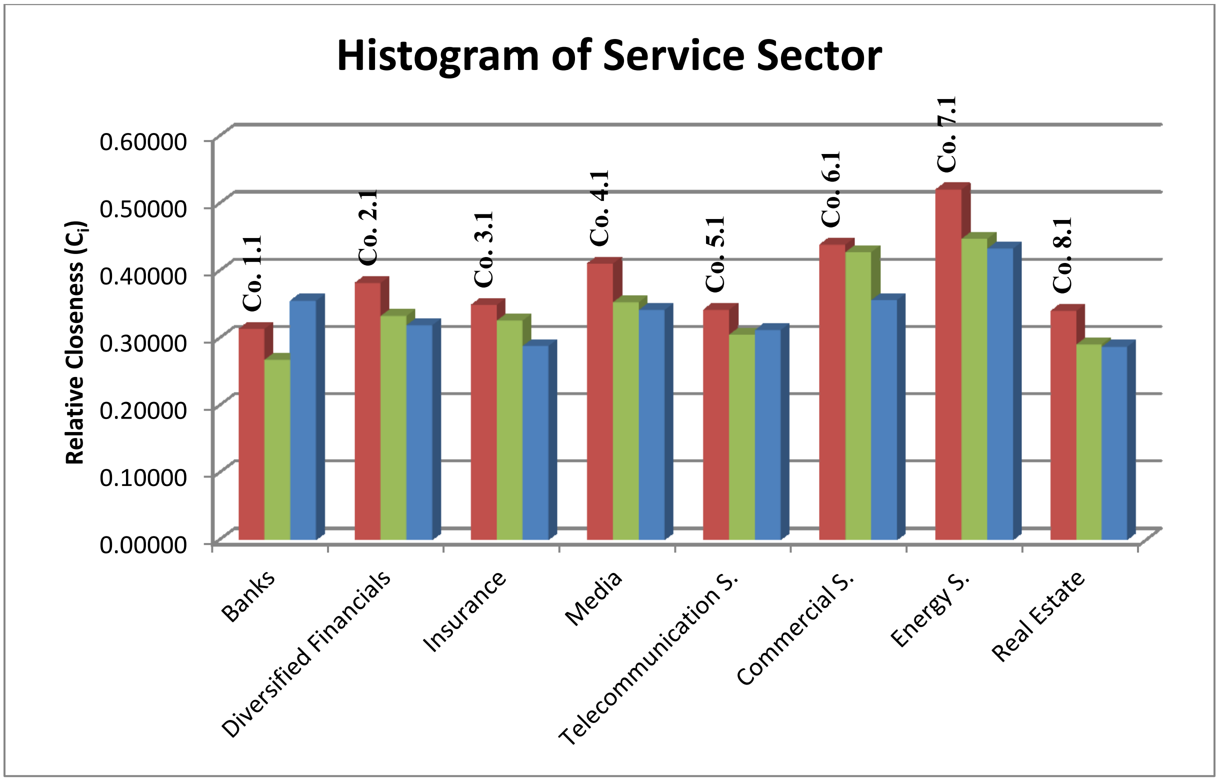


Figure 4.1 Relative Closeness (Ci) Histogram for Service Sector

4.2.5.2. Ranking the Manufacturing Sector Organizations

Table 4.8 shows TOPSIS calculations for manufacturing industries and the resulting rankings. It can be seen that most of the industries are far from the Ideal Solutions. However, many companies present a good performance with Relative Closeness more than 0.5.

Co.1.1 in Oil & Gas producers with 0.56256 receives first rank.

It means there is opportunity to increase the sustainability performance of manufacturing Industries.

The ranking of each observation includes 50 criteria and depends on the location of each individual criterion value between maximum and minimum values extracted from 24 observations for that criterion. For example, Operation Incidents values for ranking 1 and 24 are 9.36 and 5.27 respectively with maximum and minimum of 10.42 and 1.33 respectively. The same pattern can be observed for other KPIs such as Customer Incidents and Employee Incidents. The performance of each observation can be justified by comparing its outputs with maximum and minimum of each criterion.

No.	Sector	Company No.	S^+	S^-	Relative Closeness Index(Ci)	TOPSIS Ranking
1	Oil & Gas Producers (1)	Co. 1.1	10.4155	13.3947	0.56256	1
2		Co. 1.2	12.2712	12.1757	0.49805	8
3		Co. 1.3	12.6312	12.0605	0.48844	10
4	Aerospace & Defense (2)	Co. 2.1	11.2615	11.4162	0.50341	7
5		Co. 2.2	11.7927	11.0634	0.48405	13
6		Co. 2.3	12.7491	12.323	0.4915	9
7	Auto Components (3)	Co. 3.1	11.8167	12.3419	0.51087	6
8		Co. 3.2	10.984	12.4465	0.53121	4
9		Co. 3.3	11.0362	13.5173	0.55052	3
10	Transportation (4)	Co. 4.1	10.4952	12.9913	0.55314	2
11		Co. 4.2	12.6505	11.1683	0.46889	20
12		Co. 4.3	12.2134	11.4503	0.48388	14
13	Chemicals (5)	Co. 5.1	12.2365	11.6718	0.48819	11
14		Co. 5.2	12.4948	11.7242	0.48409	12
15		Co. 5.3	12.4875	10.8021	0.46382	21
16	Diversified Metals (6)	Co. 6.1	12.2415	10.9716	0.47265	19
17		Co. 6.2	12.6006	10.8338	0.4623	22
18		Co. 6.3	14.2684	8.8217	0.38206	24
19	Paper & Forestry (7)	Co. 7.1	12.5324	11.7212	0.48328	15
20		Co. 7.2	13.2031	11.2391	0.45982	23
21		Co. 7.3	12.7486	11.4983	0.47422	18
22	Precious Metals (8)	Co. 8.1	11.7775	12.8182	0.52116	5
23		Co. 8.2	13.6055	12.5904	0.48063	16
24		Co. 8.3	13.6699	12.3556	0.47475	17

Table 4.8 TOPSIS Calculations and the Resulted Rankings for Manufacturing Sector Companies

The Histogram of results is presented in The Figure 4.2.

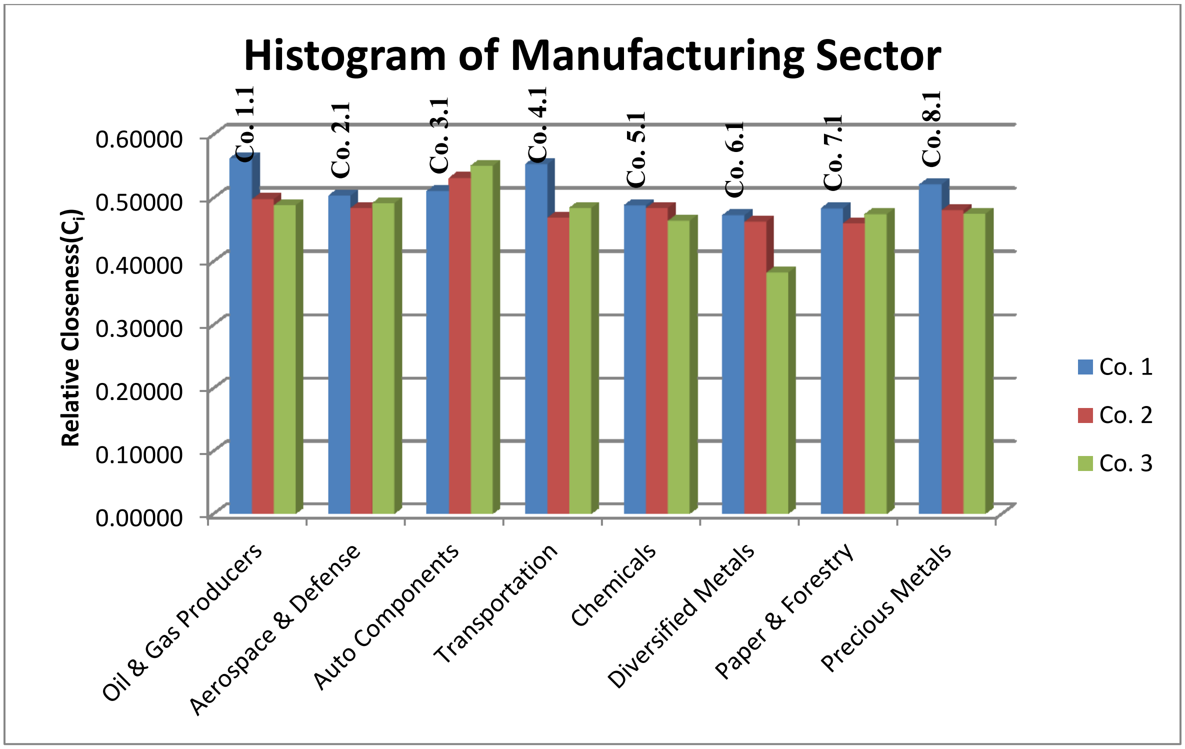


Figure 4.2 Relative Closeness (Ci) Histogram for Manufacturing Sector

4.2.6. Data Interpretation

4.2.6.1. Service Sector

By considering the Figure 4.3 and the Historam Figures (Figures 4.1 & 4.2) , we can see that in service sector the best performance among 24 sample companies belongs to Co. 7.1 and Co. 7.2 with 0.5206 and 0.44752 Relative Closeness (C_i) respectively both in Energy S. category. Energy S. category also shows the best performance among 8 different categories.

It is also considerable that among these 24 companies in service sector, most of them show the Relative Closeness (C_i) between 0.3 and 0.4 which is so far from the Ideal Solution; C_i =1. It means based on maximum and minimum performance of each criterion in this sample, there is high potential for improvement.

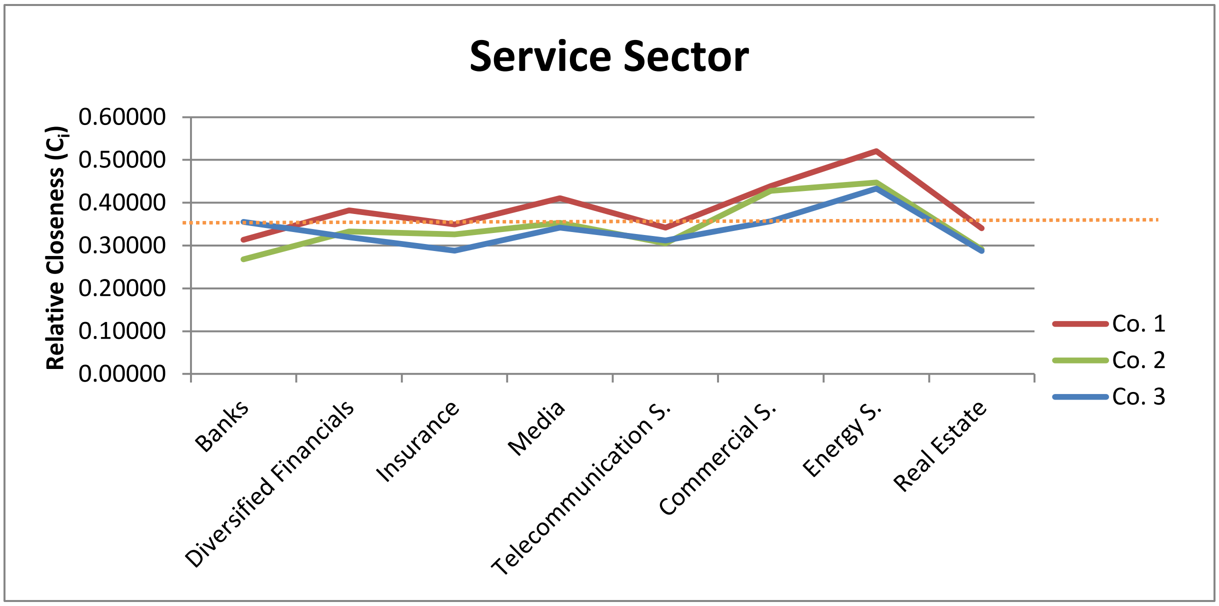
This improvement opportunity comes from the fact that observations present almost the average of industry although most of them show maximun and minimum in some criteria.

4.2.6.2. Manufacturing Sector

By considering the Figure 4.3 and the Historam Figures (Figures 4.1 & 4.2), we can see that in manufacturing sector the best performance among 24 sample companies belongs to Co. 1.1 in Oil & Gas producers and Co. 4.1 in Transportation Categories with 0.56256 and 0.55314 Relative Closeness (C_i) respectively. Nevertheless Auto Components category shows the best performance among 8 different categories with 3 companies with Relative Closeness (C_i) more than 0.5.

It is also considerable that among these 24 companies in manufacturing sector, most of them show the Relative Closeness (C_i) around 0.5 which is far from the Ideal Solution; C_i =1. It means that based on maximum and minimum performane of each criterion in this sample, there is good potential for improvement.

However we can see that between the two sectors; service and manufacturing, the performance of companies in manufacturing sector is obviously better than service sector with average Relative Closeness (C_i) 0.5 and 0.36 respectively. It means performance of companies in manufacturing sector are closer to the ideal solution of this sector compare to the same situation in service sector.



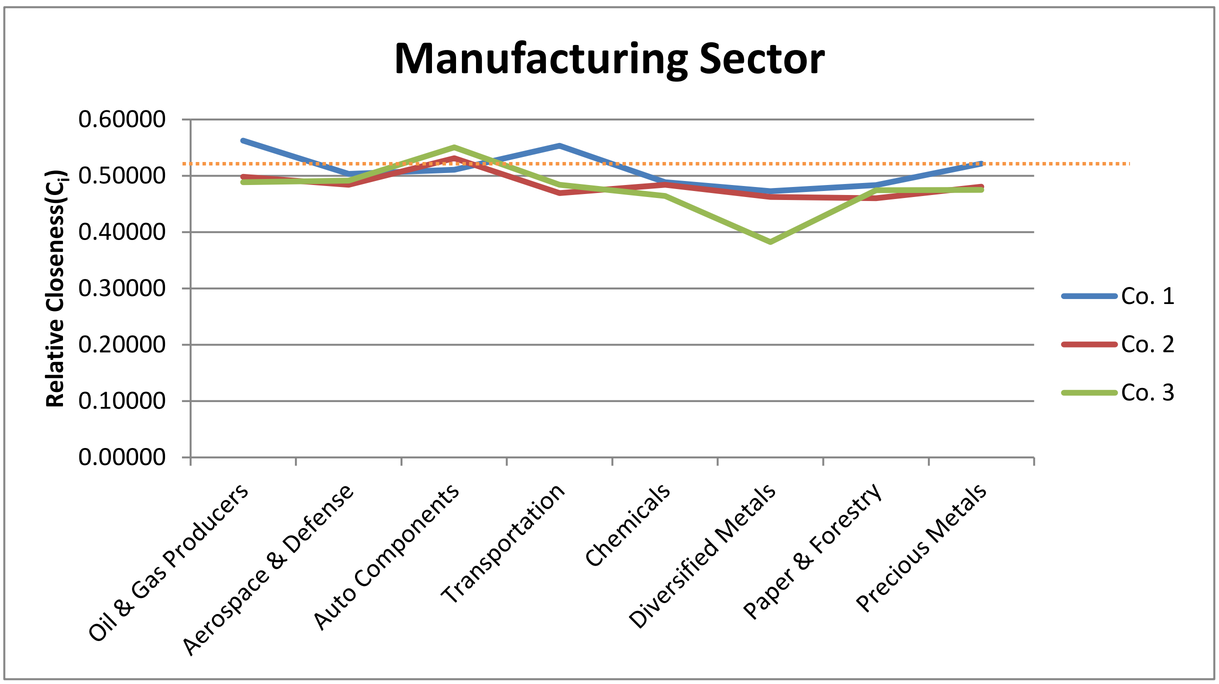


Figure 4.3 Compare Service Sector & Manufacturing Sector Results

4.2.7. Comparison of TOPSIS Results with Original Results

4.2.7.1. Service Sector

Table 4.9 and Figure 4.4 compare the ranking of each service sector company based on TOPSIS ranking and original ranking. In both, the first ranking belongs to Co. 7.1 in Energy S. category. There is close similarity in all 3 companies in Real estate category and there are more similarity, but no special pattern in matching was observed between the two models.

No.	Sector	Company No.	TOPSIS Ranking	Original Ranking
1	Banks (1)	Co. 1.1	18	7
2		Co. 1.2	24	16
3		Co. 1.3	9	18
4	Diversified Financials (2)	Co. 2.1	7	6
5		Co. 2.2	15	20
6		Co. 2.3	17	21
7	Insurance (3)	Co. 3.1	11	8
8		Co. 3.2	16	17
9		Co. 3.3	22	22
10	Media (4)	Co. 4.1	6	4
11		Co. 4.2	10	15
12		Co. 4.3	13	19
13	Telecommunication S. (5)	Co. 5.1	12	5
14		Co. 5.2	20	11
15		Co. 5.3	19	9
16	Commercial S. (6)	Co. 6.1	3	2
17		Co. 6.2	5	3
18		Co. 6.3	8	12
19	Energy S. (7)	Co. 7.1	1	1
20		Co. 7.2	2	10
21		Co. 7.3	4	14
22	Real Estate (8)	Co. 8.1	14	13
23		Co. 8.2	21	23
24		Co. 8.3	23	24

Table 4.9 TOPSIS Results vs Original Results in Service Sector

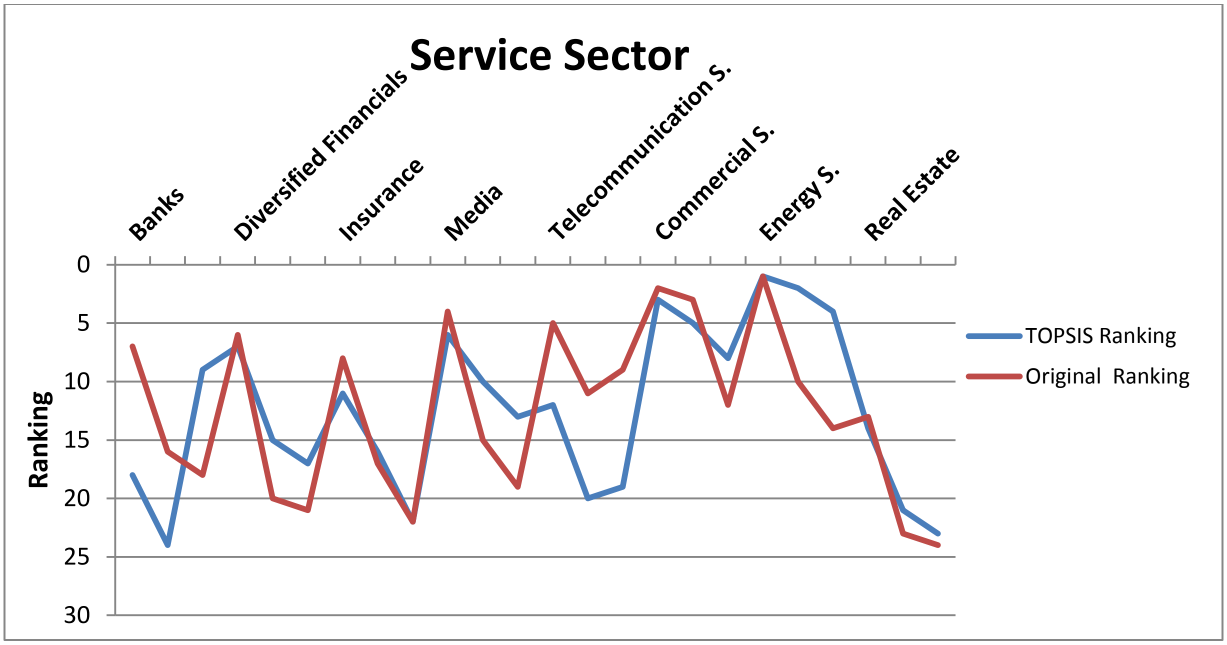


Figure 4.4 TOPSIS Results vs Original Results in Service Sector

4.2.7.2. Manufacturing Sector

Table 4.10 and Figure 4.5 compare the ranking of each manufacturing sector company based on TOPSIS ranking and original ranking. In both, the first ranking belongs to Co. 1.1 in Oil & Gas producers category. There is close similarity in all 3 companies in Chemicals category and there are more other similarity, but we can not find any special matching pattern between the two models.

No.	Sector	Company No.	TOPSIS Ranking	Original Ranking
1	Oil & Gas Producers (1)	Co. 1.1	1	1
2		Co. 1.2	8	16
3		Co. 1.3	10	20
4	Aerospace & Defense (2)	Co. 2.1	7	2
5		Co. 2.2	13	8
6		Co. 2.3	9	17
7	Auto Components (3)	Co. 3.1	6	9
8		Co. 3.2	4	5
9		Co. 3.3	3	7
10	Transportation (4)	Co. 4.1	2	3
11		Co. 4.2	20	10
12		Co. 4.3	14	15
13	Chemicals (5)	Co. 5.1	11	12
14		Co. 5.2	12	11
15		Co. 5.3	21	18
16	Diversified Metals (6)	Co. 6.1	19	4
17		Co. 6.2	22	13
18		Co. 6.3	24	19
19	Paper & Forestry (7)	Co. 7.1	15	14
20		Co. 7.2	23	21
21		Co. 7.3	18	22
22	Precious Metals (8)	Co. 8.1	5	6
23		Co. 8.2	16	23
24		Co. 8.3	17	24

Table 4.10 TOPSIS Results vs Original Results in Manufacturing Sector

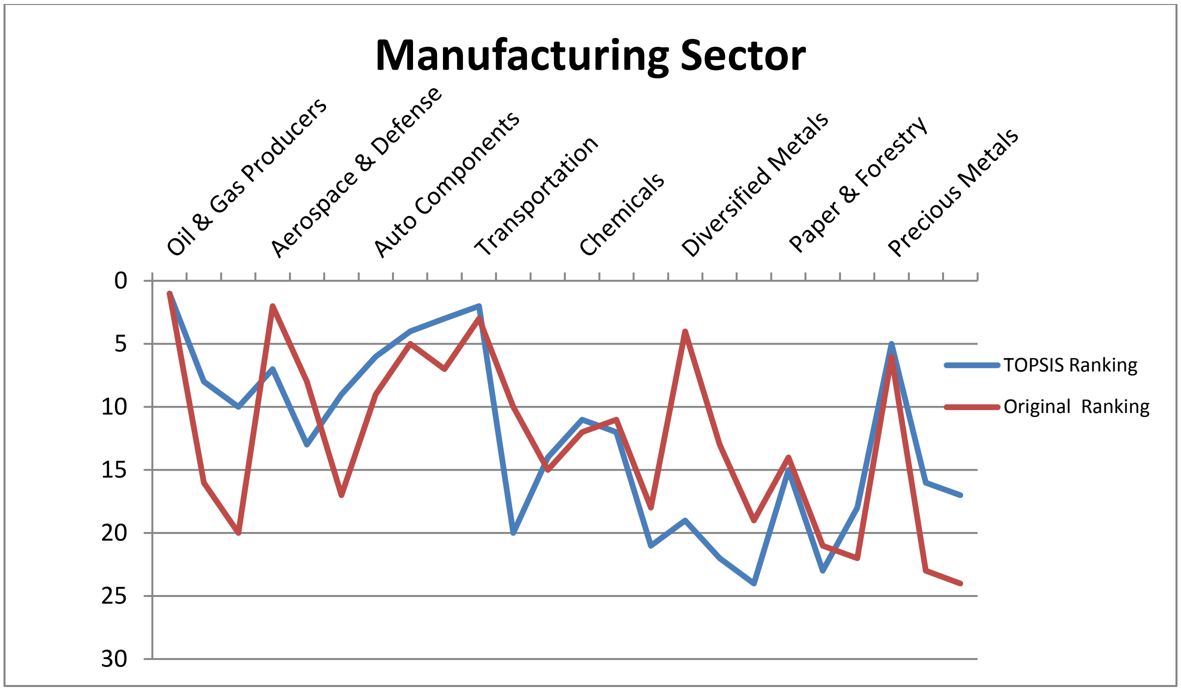


Figure 4.5 TOPSIS Results vs Original Results in Manufacturing Sector

These results are somewhat predictable and we did not expect to find any special accordance. It is understandable when we consider the concepts of calculations behind both models.

TOPSIS model behavior is based on maximum and minimum of each criteria. Therefore this model finds the solution based on the performance of companies. It recommends solutions based on Ideal and Non-Ideal situations. So we will have the rankings based on Relative Closeness values which show the distance of each observation from Ideal Solutions.

Nevertheless, in original approach cumulative criteria values are used to generate rankings. So probably we can see one company with good values in few criteria higher in the ranking than one company with better distribution in all criteria. Consequently the concept of maximum and minimum in TOPSIS model does not match the cumulative concept of original model.

4.3. Data Envelopment Analysis (DEA)

In Data Envelopment Analysis (DEA) methodology, similar to TOPSIS two sectors (manufacturing and service), each of them having 24 companies in 8 categories were considered. The manufacturing categories comprise of Oil & Gas producers, Aerospace & Defense, Auto components, Transportation, Chemicals, Diversified metals, Paper & Forestry, and Precious metals. The service categories comprise of Banks, Diversified financials, Insurance, Media, Telecommunication services, Commercial services, Energy services, and Real estate. So we compare 24 different companies in each sector to consider their operations in sustainability field. The criteria in both sectors are based on sustainability. The criteria are distributed in three dimensions: Governance, Social and Environment. In each of the dimensions, several KPI (Key Performance Indicators) are considered.

In TOPSIS methodology, 50 KPIs were considered, whereas in DEA model we integrated the KPIs and used the sub-dimensions. There are 3 integrated KPIs in Governance, 4 integrated KPIs in Social and 3 integrated KPIs in Environment. A total of 10 integrated KPIs are considered in this model. (see Table 4.11)

S. Dimensions	Governance	Social	Environment
Sub-Dimensions No.	3	4	3

Table 4.11 Sustainability Dimensions, Sub-Dimensions and relates KPIs

The same data of 50 KPIs used in TOPSIS model is also considered here; however the cumulative values for 10 integrated KPIs was used. The reason to use cumulative values was to respect the Empirical Rule for DEA. In DEA, as mentioned in Chapter 3, based on many empirical observations it is recommended that the quantity of Decision Making Units DMUs should be at least two times more than the sum of all inputs and outputs.

N (DMUs) $\geq$ 2*(Inputs + Outputs)

Considering this condition, and that we are studying 24 different observations in each sector, we reduced the quantity of KPIs by integrating them. Table 4.12 shows the list of criteria (10 integrated KPIs) used in DEA.

Dimensions	**Sub-Dimensions**
Governance	Business Ethics
	Corporate Governance
	Public Policy
Social	Employees
	Social Supply Chain
	Customers
	Society & Community
Environment	Operations Score
	Environmental Supply Chain
	Products & Services

Table 4.12 Whole Dimensions, Sub-Dimensions (Integrated KPIs)

4.3.1. Data Preparation

In Table 4.13, integrated KPI values for three companies of service sector (Bank category) are shown.

		Banks		
		Co. 1	Co. 2	Co. 3
Input		1	1	1
Output (Governance)	Business Ethics	8.09	5.69	9.71
	Corporate Governance	10.76	8.958	9.13
	Public Policy	1.6375	1.6375	2.96
Output (Social)	Employees	8.71	8.6535	6.9375
	Social Supply Chain	3.695	3.4125	1.5
	Customers	4.792	4.792	4.792
	Society & Community	3.21	3.21	4.01
Output (Environment)	Operations Score	8.375	7.425	4.65
	Environmental Supply Chain	2.2	2.2	1
	Products & Services	4	4	5

Table 4.13 Integrated KPI Values in Service Sector (Bank Category)

In appendix C the values of integrated KPIs in service sector (three categories) is presented as an embedded excel file.

Following the concept of DEA methodology, we should define the inputs and outputs among these integrated KPIs. For example, in supply chain, manufacturing, quality, logistics and transportation costs, resources used, and time spent can be considered as the inputs and the profits and products as outputs. In our database, all KPIs are outputs. The higher the value, the better it is. The Sustainalytics database does not report on the expense and resources used by the industries.

To apply DEA, we used the criteria values for outputs and for inputs, one input with value 1 was used. This implies that the cost of all companies to reach these outputs is the same.

Considering the above mentioned points, the output-oriented method was used. Keeping the input as constant, we try to improve the amount of outputs as much as possible.

4.3.2. DEA Calculation

DEA methodology is based on relative efficiency. Each company was compared with the other 23 companies to find the efficiency of investigated company in each sector. The procedure was done by using DEA frontier software and Excel Solver.

Table 4.14 presents the data and model used in our study. This table shows the calculation for first observation (Banks, Co. 1.1). Left-hand-side (LHS) and right-hand-side (RHS) formulas are shown after Table 4.14. 24 problems (one for each observation or company) will be defined in DEA and solved. The DEA results will classify the companies as efficient or inefficient and give suggestions to the inefficient companies for efficiency improvement.

		Banks			Diversified Financials		
		Co. 1.1	Co. 1.2	Co. 1.3	Co. 2.1	Co. 2.2	Co. 2.3
		λ 1	λ 2	λ 3	λ 4	λ 5	λ 6
	λ	1	1	1	1	1	1
Input		1	1	1	1	1	1
Output (Governance)	Business Ethics	8.09	5.69	9.71	10.716	9.0175	8.73
	Corporate Governance	10.76	8.958	9.13	8.1785	8.608	5.8
	Public Policy	1.6375	1.6375	2.96	2.46	1.46	2.17
Output (Social)	Employees	8.71	8.6535	6.9375	8.18	5.2825	5
	Social Supply Chain	3.695	3.4125	1.5	1.5	1.5	1.5
	Customers	4.792	4.792	4.792	5.99	5.99	5.99
	Society & Community	3.21	3.21	4.01	4.01	4.01	4.01
Output (Environment)	Operations Score	8.375	7.425	4.65	7.675	5.878	4.75
	Environmental Supply Chain	2.2	2.2	1	1.6	1	1
	Products & Services	4	4	5	6.54	5	5

Insurance			Media			Telecommunication S.			Commercial S.		
Co. 3.1	Co. 3.2	Co 3.3	Co. 4.1	Co. 4.2	Co. 4.3	Co. 5.1	Co. 5.2	Co. 5.3	Co. 6.1	Co. 6.2	Co. 6.3
λ 7	λ 8	λ 9	λ 10	λ 11	λ 12	λ 13	λ 14	λ 15	λ 16	λ 17	λ 18
1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1
10.21	9.975	8.13	7	7	6.5	8	8.8	7.5	9.3	8.5	6.5
8.009	7.6	6.654	9.45	7.8	6	11.05	8.5	9.5	9.05	8.625	7.9
2.3925	2.3925	2.21	6	6	6	2.8125	2.4375	2.4375	2.25	2.4375	2.25
6.34	6.06	5	8.704	7.61	7.61	7.05	5.7025	6.2	6.052	6.27	5
1.785	1.5	1.5	4.11	3	3	3.74	3.74	3.1525	2	2	2
5.99	4.792	5.99	5.99	5.99	5.99	3.992	3.992	4.99	5.752	2.99	2.99
3.21	4.01	3.21	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01
8.3	6.925	4	10.44	4	4	13.5325	10.655	10.443	21.75	21.25	18.8
2.2	1.6	1	6.1	4	4	4	3.2	3.2	3.6	6	2
5	5	5	2	2	2	3	3	3	2	2	2

Energy S.			Real Estate						
Co. 7.1	Co. 7.2	Co. 7.3	Co. 8.1	Co. 8.2	Co. 8.3				
λ 19	λ 20	λ 21	λ 22	λ 23	λ 24	**Q**			
1	1	1	1	1	1	1	LHS		RHS
1	1	1	1	1	1		24	<=	1
7	9	5.5	6.67	5.375	4.5		187.4135	>=	8.09
9.25	7	6.5	9.225	6.625	5.925		196.0975	>=	10.76
3	3	3	2.4	2.4375	2.4375		68.22	>=	1.6375
8.9975	6	7.0825	5.22	5.15	5.15		157.962	>=	8.71
2.665	1.5	1.7125	1.8675	1.5	1.825		55.705	>=	3.695
2.99	2.99	2.99	2.49	2.49	2.49		108.234	>=	4.792
5.01	5.01	5.01	4.01	3.01	3.01		85.04	>=	3.21
22.4	12.75	12.75	9.525	5.75	5.5		241.5235	>=	8.375
3.6	3	3	3	3	3		68.5	>=	2.2
3	3	3	7.74	7	7		96.28	>=	4

Table 4.14 DEA Calculations for First Observation (Banks, Co. 1.1)

The DEA model equations based on Table 4.14 are presented as follows:

✓ **Banks, Co. 1.1 (Observation 1):**

Max **Q**

Input:
$1\lambda_1 + 1\lambda_2 + 1\lambda_3 + 1\lambda_4 + 1\lambda_5 + 1\lambda_6 + 1\lambda_7 + \ldots + 1\lambda_{23} + 1\lambda_{24} \leq 1$

Output:
Business Ethics
$8.09\lambda_1 + 5.69\lambda_2 + 9.71\lambda_3 + 10.716\lambda_4 + 9.0175\lambda_5 + 8.73\lambda_6 + 10.21\lambda_7 + \ldots + 5.375\lambda_{23} + 4.5\lambda_{24} \geq 8.09 * \mathbf{Q}$
Corporate Governance
$10.76\lambda_1 + 8.958\lambda_2 + 9.13\lambda_3 + 8.1785\lambda_4 + 8.608\lambda_5 + 5.8\lambda_6 + 8.009\lambda_7 + \ldots + 6.625\lambda_{23} + 5.925\lambda_{24} \geq 10.76 * \mathbf{Q}$

-

-

The other integrated KPIs have the same formulas.
$\lambda_1 \geq 0, \lambda_2 \geq 0, \lambda_3 \geq 0, \lambda_4 \geq 0, \lambda_5 \geq 0, \lambda_6 \geq 0, \lambda_7 \geq 0, \ldots, \lambda_{23} \geq 0, \lambda_{24} \geq 0$

✓ **Banks, Co. 1.2 (Observation 2):**

Max **Q**

Input:
$1\lambda_1 + 1\lambda_2 + 1\lambda_3 + 1\lambda_4 + 1\lambda_5 + 1\lambda_6 + 1\lambda_7 + \ldots + 1\lambda_{23} + 1\lambda_{24} \leq 1$

Output:
Business Ethics
$8.09\lambda_1 + 5.69\lambda_2 + 9.71\lambda_3 + 10.716\lambda_4 + 9.0175\lambda_5 + 8.73\lambda_6 + 10.21\lambda_7 + \ldots + 5.375\lambda_{23} + 4.5\lambda_{24} \geq 5.69 * \mathbf{Q}$
Corporate Governance
$10.76\lambda_1 + 8.958\lambda_2 + 9.13\lambda_3 + 8.1785\lambda_4 + 8.608\lambda_5 + 5.8\lambda_6 + 8.009\lambda_7 + \ldots + 6.625\lambda_{23} + 5.925\lambda_{24} \geq 8.958 * \mathbf{Q}$

-

-

The other integrated KPIs have the same formulas.
$\lambda_1 \geq 0, \lambda_2 \geq 0, \lambda_3 \geq 0, \lambda_4 \geq 0, \lambda_5 \geq 0, \lambda_6 \geq 0, \lambda_7 \geq 0, \ldots, \lambda_{23} \geq 0, \lambda_{24} \geq 0$

4.3.3. Efficient and Inefficient Examples

4.3.3.1. Efficient Example

The initial DEA calculation for Co.1.1 in Banks category of service sector is shown in Table 4.15.

The LHS column is the numerical values as the cumulated result of the 24 companies in service sector considering λs= 1 and the RHS column is the current values of Co.1.1 considering Q = 1.

		Co. 1.1	Q			
		λ 1				
	λ	1	1	LHS		RHS
Input		1		24	<=	1
Output (Governance)	Business Ethics	8.09		187.414	>=	8.09
	Corporate Governance	10.76		196.098	>=	10.76
	Public Policy	1.6375		68.220	>=	1.6375
Output (Social)	Employees	8.71		157.962	>=	8.71
	Social Supply Chain	3.695		55.705	>=	3.695
	Customers	4.792		108.234	>=	4.792
	Society & Community	3.21		85.040	>=	3.21
Output (Environment)	Operations Score	8.375		241.524	>=	8.375
	Environmental Supply Chain	2.2		68.500	>=	2.2
	Products & Services	4		96.280	>=	4

Table 4.15 Efficient Example – Initial DEA Calculations for First Observation (Banks, Co. 1.1)

The final DEA calculation (Solver applied) for Co.1.1 in Banks category of service sector is shown in Table 4.16. The LHS column is the numerical values as the optimum results of the 24 industries (efficient average of industries) in service sector based on recommended λs and the RHS column is the recommended values for Co.1.1 considering the suggested Q.

		Co. 1.1				
		λ 1	Q			
	λ	**1**	**1**	LHS		RHS
Input		1		1	<=	1
Output (Governance)	Business Ethics	8.09		8.09	>=	8.09
	Corporate Governance	10.76		10.76	>=	10.76
	Public Policy	1.6375		1.6375	>=	1.6375
Output (Social)	Employees	8.71		8.71	>=	8.71
	Social Supply Chain	3.695		3.695	>=	3.695
	Customers	4.792		4.792	>=	4.792
	Society & Community	3.21		3.21	>=	3.21
Output (Environment)	Operations Score	8.375		8.375	>=	8.375
	Environmental Supply Chain	2.2		2.2	>=	2.2
	Products & Services	4		4	>=	4

Table 4.16 Efficient Example – Final DEA Calculations for First Observation (Banks, Co. 1.1)

As it is clear the LHS and RHS show the same result in accordance to original values of Co. 1.1. The recommended values for λs and Q are 1. It simply means the Co. 1.1 is efficient and there is not any recommendation to improve its efficiency.

4.3.3.2. Inefficient Example

The initial DEA calculation for Co.6.3 in Commercial S. category of service sector is shown in Table 4.17. The LHS column is the numerical values as the cumulated results of the 24 industries in service sector considering the λs= 1 and the RHS column is the current values of Co.6.3 considering the Q= 1.

		Co. 6.3				
		λ 18	**Q**			
	λ	1	1	LHS		RHS
Input		1		24	<=	1
Output (Governance)	Business Ethics	6.5		187.414	>=	6.5
	Corporate Governance	7.9		196.098	>=	7.9
	Public Policy	2.25		68.220	>=	2.25
Output (Social)	Employees	5		157.962	>=	5
	Social Supply Chain	2		55.705	>=	2
	Customers	2.99		108.234	>=	2.99
	Society & Community	3.01		85.040	>=	3.01
Output (Environment)	Operations Score	18.8		241.524	>=	18.8
	Environmental Supply Chain	2		68.500	>=	2
	Products & Services	2		96.280	>=	2

Table 4.17 Inefficient Example – Initial DEA Calculations for Co. 6.3 (Commercial S)

The final DEA calculation (Solver applied) for Co.6.3 in Commercial S. category of service sector is shown in Table 4.18. The LHS column is the numerical values as the optimum results of the 24 industries (efficient average of industries) in service sector based on recommended λs and the RHS column is the recommended values of Co.6.3 considering the suggested Q.

		Co. 5.1	Co. 6.1	Co. 7.1				
		λ 13	λ 16	λ 19	**Q**			
	λ	**0.02611**	**0.25291**	**0.72098**	**1.17043**	LHS		RHS
Input		1	1	1		1	<=	1
Output (Governance)	Business Ethics	8	9.3	7		7.60780	>=	7.60780
	Corporate Governance	11.05	9.05	9.25		9.24641	>=	9.24641
	Public Policy	2.8125	2.25	3		2.80542	>=	2.63347
Output (Social)	Employees	7.05	6.052	8.9975		8.20171	>=	5.85216
	Social Supply Chain	3.74	2	2.665		2.52488	>=	2.34086
	Customers	3.992	5.752	2.99		3.71470	>=	3.49959
	Society & Community	3.01	3.01	5.01		4.45196	>=	3.52300
Output (Environment)	Operations Score	13.5325	21.75	22.4		22.00411	>=	22.00411
	Environmental Supply Chain	4	3.6	3.6		3.61044	>=	2.34086
	Products & Services	3	2	3		2.74709	>=	2.34086

Table 4.18 Inefficient Example – Final DEA Calculations for Co. 6.3 (Commercial S)

It is clear the LHS and RHS show different results compared to the original values of Co. 6.3. The recommended values for λs are λ_{13} = 0.02611, λ_{16} = 0.25291, and λ_{19} = 0.72098 (based on target companies Co. 5.1, Co.6.1, Co. 7.1), and for Q is 1.17043 (See top of the Table 4.18). It simply means the Co. 6.3 is inefficient and there is good reason to give recommendation to improve the efficiency of Co. 6.3.

Summation of recommended λs is always equal to one. In this example, the accumulation of λ_{13}, λ_{16} and λ_{19} is equal to 1. The combination of λ_{13}, λ_{16} and λ_{19} will create a virtual observation for Co. 6.3 which is shown in the LHS column. In this way DEA defines a virtual observation in the reference set column (LHS) by multiplying each criterion to λ_{13}, λ_{16} and λ_{19} to create new criterion in reference set as a virtual target for alternative under observation. Co. 6.3 can consider these values in LHS as objectives for future improvements.

For example for Business Ethics criterion in table 4.18 we have:

$\lambda_{13}*8 + \lambda_{16}*9.3 + \lambda_{19}*7 = 0.02611*8 + 0.25291*9.3 + 0.72098*7 = 7.6078$ (shown in LHS column)

However because of theoretical limitations, Co. 6.3 just can reach the RHS column values considering Q = 1.17043.

To summarize, in Table 4.19 the original and target values of Co. 6.3 are presented.

		Original Values	Target values
Output (Governance)	Business Ethics	6.5	7.6078
	Corporate Governance	7.9	9.24641
	Public Policy	2.25	2.63347
Output (Social)	Employees	5	5.85216
	Social Supply Chain	2	2.34086
	Customers	2.99	3.49959
	Society & Community	3.01	3.523
Output (Environment)	Operations Score	18.8	22.00411
	Environmental Supply Chain	2	2.34086
	Products & Services	2	2.34086

Table 4.19 Summarized Result of Inefficient Example

4.3.4. DEA Results

4.3.4.1. Service Results

Considering the explanation presented in *Efficient and Inefficient Examples* part, the total results of all 24 companies investigated in service sector are shown in Table 4.20 and Figure 4.6. In this Table, there are recommendations for each companies based on the calculations.

For efficient companies, the recommendations are the same companies with Q = 1. For inefficient companies, there are one or more different recommended companies to increase the efficiency of observed company. The effect of each recommendation is shown as λ. In these cases Coefficient score (Q) for observed companies will be more than 1 as in output-oriented model, inefficiency are defined with Coefficient score (Q) more than 1.

	Co. No.	Coefficient score (Q)	Efficiency result	Recommended companies with λs
Banks (1)	**Co. 1.1**	1	Efficient	Co. 1.1 (1)
	Co. 1.2	1.005557	Inefficient	Co. 1.1 (0.96979), Co. 2.1 (0.0175) Co. 4.1 (0.00952) Co. 7.1 (0.003188)
	Co. 1.3	1	Efficient	Co. 1.3 (1)
Diversified Financials (2)	**Co. 2.1**	1	Efficient	Co. 2.1 (1)
	Co. 2.2	1	Efficient	Co. 2.2 (1)
	Co. 2.3	1.001672	Inefficient	Co. 2.1 (0.698597) Co. 2.2 (0.298092) Co. 4.1 (0.003311)
Insurance (3)	**Co. 3.1**	1	Efficient	Co. 3.1 (1)
	Co. 3.2	1.038417	Inefficient	Co. 2.1 (0.794496) Co. 5.2 (0.025726) Co. 7.2 (0.179778)
	Co. 3.3	1	***Efficient or Inefficient***	Co. 2.1 (0.660793) Co. 4.1 (0.339207)
Media (4)	**Co. 4.1**	1	Efficient	Co. 4.1 (1)
	Co. 4.2	1	***Efficient or Inefficient***	Co. 4.1 (1)
	Co. 4.3	1	***Efficient or Inefficient***	Co. 4.1 (1)

	Co. No.	Coefficient score (Q)	Efficiency result	Recommended companies with λs
Telecommunication S. (5)	**Co. 5.1**	1	Efficient	Co. 5.1 (1)
	Co. 5.2	1	Efficient	Co. 5.2 (1)
	Co. 5.3	1.057684	Inefficient	Co. 1.1 (0.533163) Co. 2.2 (0.04267) Co. 4.1 (0.256783) Co. 6.1 (0.155222) Co. 7.1 (0.012163)
Commercial S. (6)	**Co. 6.1**	1	Efficient	Co. 6.1 (1)
	Co. 6.2	1	Efficient	Co. 6.2 (1)
	Co. 6.3	1.170431	Inefficient	Co. 5.1 (0.026106) Co. 6.1 (0.252912) Co. 7.1 (0.720982)
Energy S. (7)	**Co. 7.1**	1	Efficient	Co. 7.1 (1)
	Co. 7.2	1	Efficient	Co. 7.2 (1)
	Co. 7.3	1	Efficient	Co. 7.3 (1)
Real Estate (8)	**Co. 8.1**	1	Efficient	Co. 8.1 (1)
	Co. 8.2	1.056867	Inefficient	Co. 2.1 (0.006867) Co. 4.1 (0.058134) Co. 8.1 (0.934999)
	Co. 8.3	1.056867	Inefficient	Co. 2.1 (0.006867) Co. 4.1 (0.058134) Co. 8.1 (0.934999)

Table 4.20 DEA Service Results

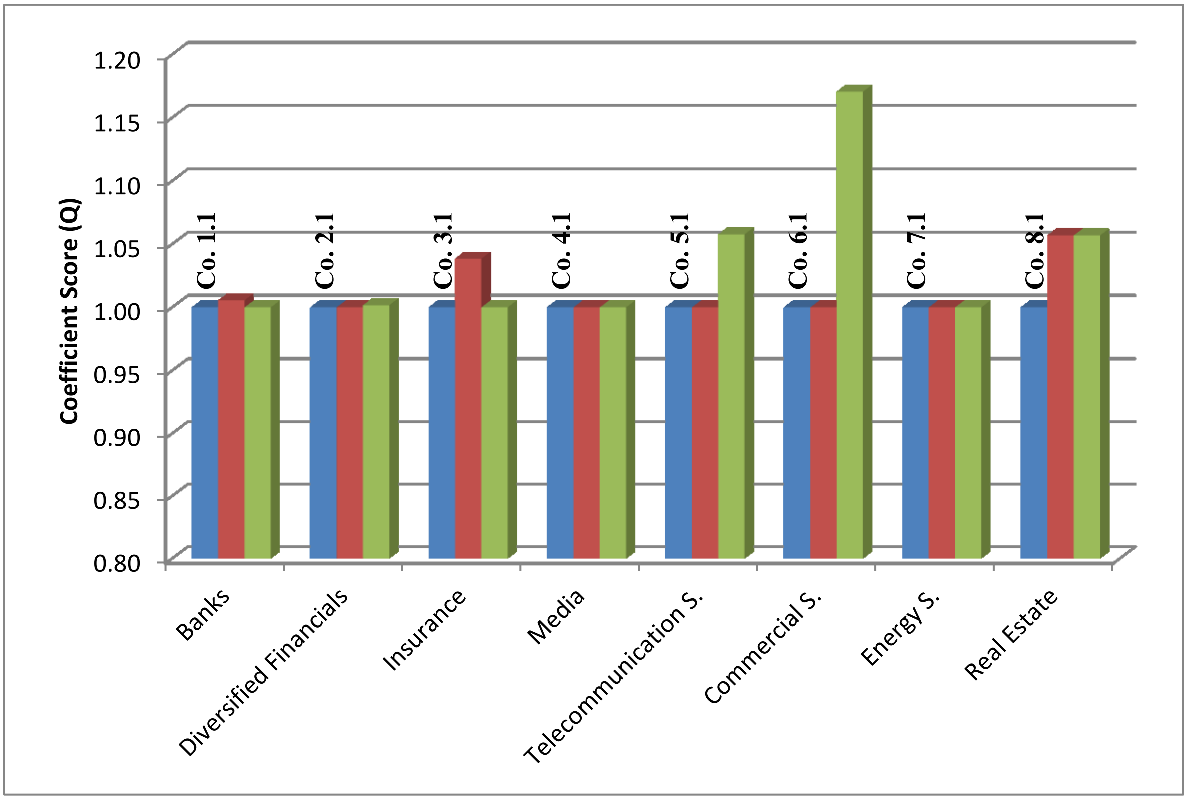


Figure 4.6 DEA Coefficient Score (Q) - Service Results

4.3.4.2. Manufacturing Results

Considering the explanation presented in *Efficient and Inefficient Examples* part, the total results of all 24 companies investigated in manufacturing sector are shown in Table 4.21 and Figure 4.7. In this Table, there are recommendations for each companies based on the calculation.

For efficient companies, the recommendations are the same companies with Q = 1. For inefficient companies, there are one or more different recommended companies to increase the efficiency of observed company. The effect of each recommendation is shown as λ. In these cases coefficient score (Q) for observed companies will be more than 1 as in output-oriented model, inefficiency are defined with coefficient score (Q) more than 1.

	Co. No.	**Coefficient score (Q)**	**Efficiency result**	**Recommended companies with λs**
Oil & Gas Producers (1)	**Co. 1.1**	1	Efficient	Co. 1.1 (1)
	Co. 1.2	1	Efficient	Co. 1.2 (1)
	Co. 1.3	1	***Efficient or Inefficient***	Co. 1.2 (1)
Aerospace & Defense (2)	**Co. 2.1**	1	Efficient	Co. 2.1 (1)
	Co. 2.2	1	Efficient	Co. 2.2 (1)
	Co. 2.3	1	Efficient	Co. 2.3 (1)
Auto Components (3)	**Co. 3.1**	1	Efficient	Co. 3.1 (1)
	Co. 3.2	1	Efficient	Co. 3.2 (1)
	Co. 3.3	1	Efficient	Co. 3.3 (1)
Transportation (4)	**Co. 4.1**	1	Efficient	Co. 4.1 (1)
	Co. 4.2	1	Efficient	Co. 4.2 (1)
	Co. 4.3	1.015566	Inefficient	Co. 2.3 (0.067719) Co. 3.3 (0.401644) Co. 4.1 (0.391561) Co. 6.1 (0.139076)

	Co. No.	Coefficient score (Q)	Efficiency result	Recommended companies with λs
Chemicals (5)	**Co. 5.1**	1	Efficient	Co. 5.1 (1)
	Co. 5.2	1.019495	Inefficient	Co. 1.1 (0.004702) Co. 3.2 (0.041341) Co. 4.1 (0.726071) Co. 5.1 (0.227886)
	Co. 5.3	1.04143	Inefficient	Co. 2.3 (0.114585) Co. 3.3 (0.304732) Co. 4.1 (0.385603) Co. 6.1 (0.195079)
Diversified Metals (6)	**Co. 6.1**	1	Efficient	Co. 6.1 (1)
	Co. 6.2	1.026233	Inefficient	Co. 2.3 (0.128449) Co. 3.3 (0.052467) Co. 4.1 (0.03342) Co. 6.1 (0.657448) Co. 8.1 (0.128216)
	Co. 6.3	1.084155	Inefficient	Co. 2.3 (0.058056) Co. 3.3 (0.168311) Co. 6.1 (0.773633)
Paper & Forestry (7)	**Co. 7.1**	1.059767	Inefficient	Co. 1.1 (0.522665) Co. 2.3 (0.230128) Co. 6.1 (0.247206)
	Co. 7.2	1.141215	Inefficient	Co. 1.1 (0.301721) Co. 2.3 (0.209555) Co. 4.1 (0.340402) Co. 6.1 (0.148323)
	Co. 7.3	1.036625	Inefficient	Co. 1.1 (0.321205) Co. 2.3 (0.295082) Co. 4.1 (0.0157) Co. 6.1 (0.368013)
Precious Metals (8)	**Co. 8.1**	1	Efficient	Co. 8.1 (1)
	Co. 8.2	1	***Efficient or Inefficient***	Co. 6.1 (0.570934) Co. 8.3 (0.429066)
	Co. 8.3	1	Efficient	Co. 8.3 (1)

Table 4.21 DEA Manufacturing Results

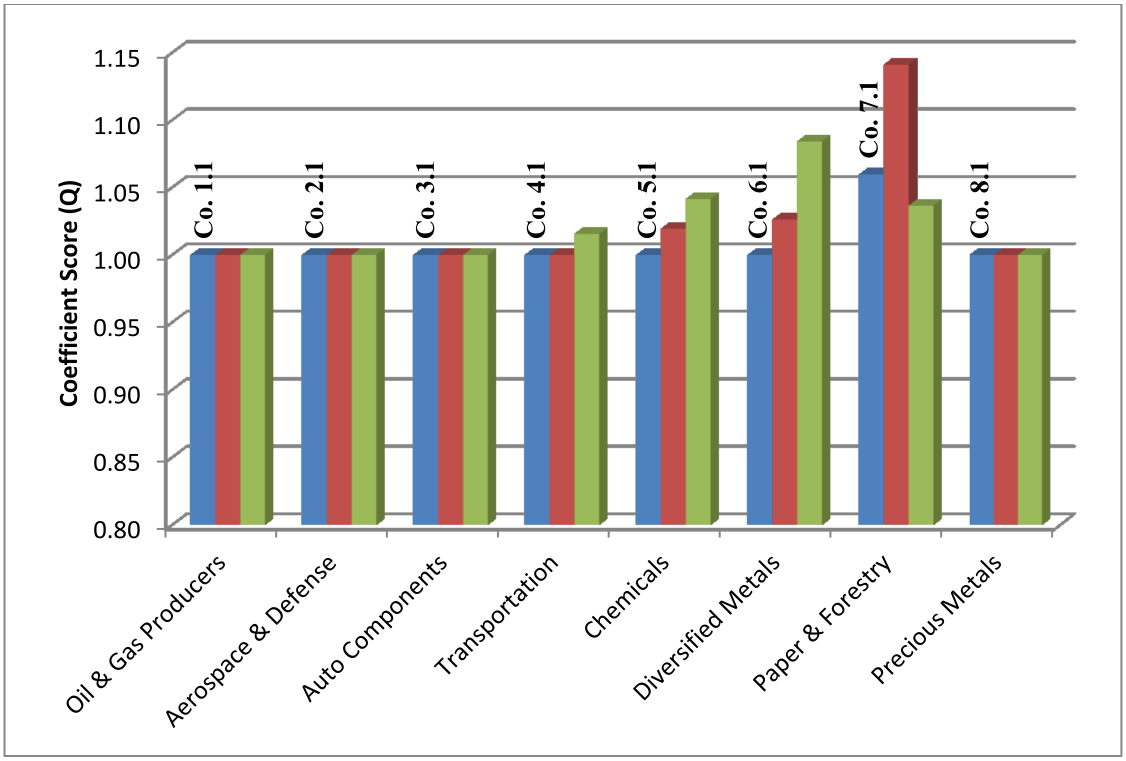


Figure 4.7 DEA Coefficient Score (Q) - Manufacturing Results

4.3.5. DEA Interpretation

The interpretation of results of previous part (DEA Results) is not easy. Although DEA is a good tool to investigate the results in many different areas, here in our database we had many limitations to use and translate the results.

4.3.5.1. Efficient or Inefficient

For example in service sector there were recommendations for improvement of 3 companies; Co. 3.3 in Insurance category, Co. 4.2, Co.4.3 in Media category, however because of similarity in some KPIs value in recommended companies with the observed company, theoretically DEA cannot show coefficient value more than 1 to highlight the observed company as an inefficient company.

It is because of the inherent problem of DEA. When we have even one KPI similar between two companies, DEA cannot consider one of them inefficient.

Then, although we can see some inefficiency in these kinds of companies, we should theoretically consider them as efficient ones.

We had the same problems for two companies in manufacturing sector; Co. 1.3 in Oil & Gas producers category and Co. 8.2 in Precious metals category.

4.3.5.2. Limitation in KPIs with Maximum Value

There is another limitation in DEA model. In our output-oriented model of DEA, which is a model to increase the output value, we considered that among companies, each company that has at least one KPI with maximum value, does not show inefficiency even if the other KPIs have small value compare to other companies performance.

This will apply even if this maximum value is repeated in more than one company. In this situation, all companies that have maximum value in common remain efficient no matter of the other KPIs value.

In addition, despite respecting the Empirical Rules (Chapter 3), which lowered 50 KPIs to 10 integrated KPIs, the problem did not eradicate completely.

The nature of KPIs in our sustainability model (output-oriented model) and the ratio of KPIs no. to companies no. did not allow us to implement efficient and inefficient model so properly.

However, we had good results with 10 inefficient companies in each sector in finding suggestions.

Table 4.22 compares the result of original ranking with DEA coefficient score (Q) in service sector. The inefficient companies have coefficient more than 1 and some companies with coefficient 1 (the companies that were explained in ***Efficient or Inefficient*** part) are shown by italic font. We can see here that high ranked companies in original ranking (the best one has ranking 1) show efficiency and the low rank ones show inefficiency.

No.	Sector	Company No.	Original Ranking	DEA Coefficient
1	Banks (1)	Co. 1.1	7	1
2		Co. 1.2	16	1.00556
3		Co. 1.3	18	1
4	Diversified Financials (2)	Co. 2.1	6	1
5		Co. 2.2	20	1
6		Co. 2.3	21	1.00167
7	Insurance (3)	Co. 3.1	8	1
8		Co. 3.2	17	1.03842
9		Co. 3.3	22	*1*
10	Media (4)	Co. 4.1	4	1
11		Co. 4.2	15	*1*
12		Co. 4.3	19	*1*
13	Telecommunication S. (5)	Co. 5.1	5	1
14		Co. 5.2	11	1
15		Co. 5.3	9	1.05768
16	Commercial S. (6)	Co. 6.1	2	1
17		Co. 6.2	3	1
18		Co. 6.3	12	1.17043
19	Energy S. (7)	Co. 7.1	1	1
20		Co. 7.2	10	1
21		Co. 7.3	14	1
22	Real Estate (8)	Co. 8.1	13	1
23		Co. 8.2	23	1.05687
24		Co. 8.3	24	1.05687

Table 4.22 Comparing Original Ranking with DEA Coefficient Score (Q) in Service Sector

Table 4.23 compares the result of original ranking with DEA coefficient score (Q) in manufacturing sector. The inefficient companies have coefficient more than 1 and some companies with coefficient 1 (the companies that were explained in ***Efficient or Inefficient*** part) are shown in italics. We can see here that high ranked companies in original ranking (the best one has ranking 1) show efficiency and low ranked show inefficiency.

No.	Sector	Company No.	Original Ranking	DEA Coefficient
1	Oil & Gas Producers (1)	Co. 1.1	1	1
2		Co. 1.2	16	1
3		Co. 1.3	20	*1*
4	Aerospace & Defense (2)	Co. 2.1	2	1
5		Co. 2.2	8	1
6		Co. 2.3	17	1
7	Auto Components (3)	Co. 3.1	9	1
8		Co. 3.2	5	1
9		Co. 3.3	7	1
10	Transportation (4)	Co. 4.1	3	1
11		Co. 4.2	10	1
12		Co. 4.3	15	1.01557
13	Chemicals (5)	Co. 5.1	12	1
14		Co. 5.2	11	1.01949
15		Co. 5.3	18	1.04143
16	Diversified Metals (6)	Co. 6.1	4	1
17		Co. 6.2	13	1.02623
18		Co. 6.3	19	1.08416
19	Paper & Forestry (7)	Co. 7.1	14	1.05977
20		Co. 7.2	21	1.14122
21		Co. 7.3	22	1.03663
22	Precious Metals (8)	Co. 8.1	6	1
23		Co. 8.2	23	*1*
24		Co. 8.3	24	1

Table 4.23 Comparing Original Ranking with DEA Coefficient Score (Q) in Manufacturing Sector

Chapter 5:

Conclusions & Future Works

5.1. Conclusion

In this thesis we proposed a multicriteria framework for benchmarking sustainability performance of organizations using TOPSIS and DEA method. TOPSIS ranks the organizations based on relative closeness to ideal and non-ideal solutions. The best alternative is closest to the ideal solution and farthest from the non-ideal solution. DEA ranks the organizations as efficient or inefficient based on the concept of relative efficiency. The efficient organizations have a relative efficiency of 1. For inefficient organizations, DEA will show the suggestions for improvement based on the performance of others.

The indicators for sustainability measurement are developed using Sustainalytics database. The proposed techniques are applied on available data for Canadian companies. Two sectors (service and manufacturing) are considered. In each sector, eight categories and in each category three companies are evaluated making a total of 24 companies (or observations) in each sector.

The results of our TOPSIS study show:

- Energy category shows the best performance among 8 different categories in service sector.
- Auto components category shows the best performance among 8 different categories in manufacturing sector with 3 companies having Relative Closeness (C_i) values more than 0.5.
- Among service and manufacturing, the manufacturing sector shows better performance with average Relative Closeness (C_i) values 0.5 and 0.36 respectively.

The DEA method yielded 10 inefficient companies in each sector and provided targets for improvement.

5.2. Future Works

Finally, this research has some limitations which can be translated into opportunities for further research as follows:

- In the proposed KPIs, financial dimension can be added.
- Other frameworks for example Global Reporting Initiative (GRI) and Dow Jones Sustainability Index (DJSI) can be considered to develop the model.
- As Sustainalytics database covers different regions, countries and industries, the context of country and multiple sectors could be further investigated.
- Combination of other MCDM techniques such as AHP with TOPSIS can be considered. Different types of fuzzy methods can also be investigated.
- Other types of efficiency definitions and various types of DEA method can also be added to study.

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Appendices

Appendix A:

Theme	Category	Indicator Name	Indicator Number
Governance	Preparedness	Bribery & Corruption Policy	G.1.1
Governance	Preparedness	Bribery & Corruption Programmes	G.1.1.1
Governance	Preparedness	Whistleblower Programmes	G.1.2
Governance	Preparedness	Global Compact Signatory	G.1.3
Governance	Preparedness	PRI Signatory	G.1.3.1
Governance	Preparedness	Responsible Investment Policy	G.1.3.2
Governance	Preparedness	UNEPFI Signatory	G.1.3.3
Governance	Preparedness	Green Building Memberships	G.1.3.4
Governance	Preparedness	Equator Principles Signatory	G.1.3.5
Governance	Disclosure	Tax Disclosure	G.1.4
Governance	Preparedness	Money Laundering Policy	G.1.4.1
Governance	Preparedness	Animal Testing Policy	G.1.4.3
Governance	Preparedness	Animal Welfare Policy	G.1.4.4
Governance	Preparedness	Genetic Engineering Policy	G.1.4.5
Governance	Preparedness	Clinical Trial Standards	G.1.4.6
Governance	Qualitative Performance	Business Ethics Incidents	G.1.5
Governance	Disclosure	ESG Reporting Standards	G.2.1
Governance	Disclosure	Verification of ESG Reporting	G.2.2
Governance	Disclosure	Board Remuneration Disclosure	G.2.3
Governance	Disclosure	Board Biographies Disclosure	G.2.4
Governance	Preparedness	ESG Governance	G.2.5
Governance	Preparedness	Responsible Investment Team	G.2.5.1
Governance	Preparedness	ESG Performance Targets	G.2.6
Governance	Preparedness	Gender Diversity of Board	G.2.7
Governance	Preparedness	Separation of Chair & CEO	G.2.8
Governance	Preparedness	Board Independence	G.2.9
Governance	Preparedness	Audit Committee Independence	G.2.10
Governance	Preparedness	Non-Audit to Audit Fee Ratio	G.2.11
Governance	Preparedness	Compensation Committee Independence	G.2.12
Governance	Qualitative Performance	Governance Incidents	G.2.13
Governance	Preparedness	Political Involvement Policy	G.3.1
Governance	Preparedness	Lobbying and Political Expenses	G.3.2
Governance	Disclosure	Transparency on Government Payments	G.3.3.1
Governance	Qualitative Performance	Public Policy Incidents	G.3.4
Social	Preparedness	Freedom of Association Policy	S.1.1
Social	Preparedness	Working Conditions Policy	S.1.1.1
Social	Preparedness	Discrimination Policy	S.1.2
Social	Preparedness	Diversity Programmes	S.1.3
Social	Quantitative Performance	Collective Bargaining Agreements	S.1.4

Social	Quantitative Performance	Employee Turnover Rate	S.1.5
Social	Quantitative Performance	Percentage of Temporary Workers	S.1.5.1
Social	Quantitative Performance	Employee Training	S.1.6.1
Social	Preparedness	Health and Safety Management System	S.1.6.2.1
Social	Preparedness	HIV/Aids Programmes	S.1.6.3
Social	Preparedness	Health & Safety Certifications	S.1.6.4
Social	Quantitative Performance	LTIR Trend	S.1.6.5
Social	Quantitative Performance	Employee Fatalities	S.1.6.6
Social	Qualitative Performance	Employee Incidents	S.1.7
Social	Preparedness	Scope of Social Supplier Standards	S.2.1
Social	Preparedness	Quality of Social Supplier Standards	S.2.1.1
Social	Preparedness	EICC Signatory	S.2.1.2
Social	Preparedness	Conflict Minerals Policy	S.2.1.3
Social	Preparedness	Conflict Minerals Programmes	S.2.1.3.1
Social	Preparedness	Supply Chain Monitoring	S.2.2
Social	Preparedness	Supply Chain Audits	S.2.2.1
Social	Disclosure	Supply Chain Disclosure	S.2.2.2
Social	Preparedness	Supply Chain Management	S.2.2.2.1
Social	Preparedness	Social Supplier Certification	S.2.2.3
Social	Quantitative Performance	Fair Trade Products	S.2.2.4
Social	Qualitative Performance	Social Supply Chain Incidents	S.2.3
Social	Preparedness	Responsible Marketing Policy	S.3.1.1
Social	Preparedness	Advertising Ethics Policy	S.3.1.2
Social	Preparedness	Data Privacy Policy	S.3.1.3
Social	Preparedness	Electromagnetic Safety Programmes	S.3.1.4
Social	Preparedness	Editorial Outsourcing	S.3.1.5
Social	Preparedness	Editorial Guidelines	S.3.1.6
Social	Preparedness	Conflict of Interest Policy	S.3.1.7
Social	Quantitative Performance	Flights Delays	S.3.1.8
Social	Preparedness	Product Health Statement	S.3.1.9
Social	Preparedness	Occupier Satisfaction Surveys	S.3.1.10
Social	Preparedness	Customer Eco-Efficiency Programmes	S.3.1.11
Social	Preparedness	Drug Promotion Standards	S.3.1.12
Social	Preparedness	QMS Certifications	S.3.2.1
Social	Qualitative Performance	Customer Incidents	S.3.3
Social	Quantitative Performance	Activities in Sensitive Countries	S.4.1
Social	Preparedness	Human Rights Policy	S.4.2.1
Social	Preparedness	Community Involvement Programmes	S.4.2.2
Social	Preparedness	Financial Inclusion	S.4.2.3
Social	Preparedness	Access to Medicine Programme	S.4.2.4
Social	Preparedness	Neglected Diseases R&D	S.4.2.5
Social	Preparedness	Equitable Pricing and Availability	S.4.2.6
Social	Preparedness	Access to Health Care	S.4.2.7
Social	Preparedness	Independent Media Programmes	S.4.2.8
Social	Preparedness	Indigenous Rights Policy	S.4.2.9

Social	Preparedness	Access to Basic Services	S.4.2.10
Social	Preparedness	Community Development Programmes	S.4.2.11
Social	Preparedness	Digital Divide Programmes	S.4.2.12
Social	Preparedness	Drug Donations Policy	S.4.2.13
Social	Quantitative Performance	Value of Drug Donations	S.4.2.14
Social	Qualitative Performance	Society & Community Incidents	S.4.3
Environment	Preparedness	Environmental Policy	E.1.1
Environment	Disclosure	Environmental Reporting	E.1.1.1
Environment	Preparedness	Environmental Management System	E.1.2
Environment	Preparedness	Biodiversity Programmes	E.1.2.1
Environment	Preparedness	Site Closure & Rehabilitation	E.1.2.2
Environment	Preparedness	Sustainability Impact Assessments	E.1.2.3
Environment	Disclosure	Oil Spill Disclosure & Performance	E.1.2.4
Environment	Quantitative Performance	Water Intensity	E.1.2.7
Environment	Quantitative Performance	Forest Certifications	E.1.2.8
Environment	Quantitative Performance	Forest Certifications	E.1.2.8
Environment	Preparedness	EMS Certification	E.1.3
Environment	Preparedness	Hazardous Waste Management	E.1.3.2
Environment	Preparedness	Air Emissions Programmes	E.1.3.3
Environment	Preparedness	Water Management Programmes	E.1.3.4
Environment	Preparedness	Other Environmental Programmes	E.1.3.5
Environment	Quantitative Performance	Environmental Fines & Penalties	E.1.4
Environment	Disclosure	CDP Participation	E.1.5
Environment	Disclosure	Scope of GHG Reporting	E.1.6
Environment	Preparedness	GHG Reduction Programme	E.1.7.0
Environment	Preparedness	Green Logistics Programmes	E.1.7.1
Environment	Preparedness	HCFCs Phase Out	E.1.7.2
Environment	Preparedness	Renewable Energy Programmes	E.1.8
Environment	Quantitative Performance	Carbon Intensity	E.1.9
Environment	Quantitative Performance	Carbon Intensity Trend	E.1.10
Environment	Quantitative Performance	Renewable Energy Use	E.1.11
Environment	Qualitative Performance	Operations Incidents	E.1.12
Environment	Preparedness	Green Procurement Policy	E.2.1
Environment	Preparedness	Supplier Environmental Programmes	E.2.1.1
Environment	Preparedness	Supplier Environmental Certifications	E.2.1.2
Environment	Preparedness	Sustainable Agriculture Programmes	E.2.1.3
Environment	Preparedness	Sustainable Aquaculture Programmes	E.2.1.4
Environment	Preparedness	Food & Beverage Sustainability Initiatives	E.2.1.5
Environment	Preparedness	Green Outsourced Logistics Programmes	E.2.1.6
Environment	Quantitative Performance	Recycled Material Use	E.2.1.7
Environment	Quantitative Performance	FSC Certified Sourcing	E.2.1.8
Environment	Preparedness	Sustainable Food Programmes	E.2.1.9
Environment	Preparedness	Food Retail Initiatives	E.2.1.10

Environment	Qualitative Performance	Environmental Supply Chain Incidents	E.2.2
Environment	Quantitative Performance	Sustainable Products & Services	E.3.1.1
Environment	Quantitative Performance	Clean Technology Revenues	E.3.1.2
Environment	Quantitative Performance	Fleet Emissions	E.3.1.3
Environment	Quantitative Performance	Fleet Efficiency	E.3.1.4
Environment	Quantitative Performance	Sustainable Mobility Products	E.3.1.5
Environment	Preparedness	Eco-Design	E.3.1.6
Environment	Preparedness	Product Stewardship Programmes	E.3.1.7
Environment	Quantitative Performance	Organic Products	E.3.1.8
Environment	Preparedness	GMO Policy	E.3.1.9
Environment	Preparedness	Credit & Loan Standards	E.3.1.10
Environment	Quantitative Performance	Responsible Asset Management	E.3.1.11
Environment	Preparedness	Real Estate LCA	E.3.1.12
Environment	Preparedness	Green Buildings Investments	E.3.1.13
Environment	Quantitative Performance	Share of Green Buildings	E.3.1.14
Environment	Quantitative Performance	Sustainable Financial Services	E.3.1.15
Environment	Quantitative Performance	Hazardous Products	E.3.1.16
Environment	Quantitative Performance	Energy Mix	E.3.1.17
Environment	Qualitative Performance	Product & Service Incidents	E.3.2

Appendix B:

			Banks			Diversified Financials			Insurance		
			Co. 1	Co. 2	Co. 3	Co. 4	Co. 5	Co. 6	Co. 7	Co. 8	Co. 9
Governance	Business Ethics	G.1.1	0.4600	0.4600	0.4800	0.4350	0.1600	0.1150	0.4900	0.7350	0.4900
		G.1.2	1.2300	1.2300	1.2300	1.2550	0.8575	0.6150	1.2400	1.2400	1.2400
		G.1.3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.4800	0.0000	0.0000
		G.1.4	0.0000	0.0000	0.0000	1.0260	0.0000	0.0000	0.0000	0.0000	0.0000
		G.1.5	6.4000	4.0000	8.0000	8.0000	8.0000	8.0000	8.0000	8.0000	6.4000
	Corporate Governance	G.2.1	0.7200	0.4800	0.0000	0.2525	0.0000	0.0000	0.0000	0.2450	0.0000
		G.2.2	0.4800	0.4800	0.0000	0.5050	0.0000	0.0000	0.0000	0.0000	0.0000
		G.2.3	0.2100	0.2100	0.0000	0.2600	0.2900	0.0000	0.2300	0.2300	0.2300
		G.2.4	0.2100	0.2100	0.0000	0.2600	0.2900	0.0000	0.2300	0.2300	0.2300
		G.2.5	0.9600	0.9600	0.0000	1.0100	0.5360	0.0000	0.9800	0.9800	0.2940
		G.2.6	0.9600	0.2400	0.0000	0.2525	0.0000	0.0000	0.0000	0.0000	0.0000
		G.2.7	0.9600	0.9600	0.0000	0.6060	1.0720	0.0000	0.7840	0.9800	0.0000
		G.2.8	0.4600	0.4600	2.2100	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		G.2.9	0.9600	0.9600	2.7100	0.2525	1.3400	0.9600	0.9800	0.2450	0.9800
		G.2.10	0.2100	0.2100	0.0000	0.2600	0.2900	0.2100	0.2300	0.2300	0.2300
		G.2.11	0.2100	0.2100	0.0000	0.2600	0.2900	0.2100	0.1150	0.2300	0.2300
		G.2.12	0.2100	0.2100	0.0000	0.0000	0.2900	0.2100	0.2300	0.0000	0.2300
		G.2.13	4.2100	3.3680	4.2100	4.2600	4.2100	4.2100	4.2300	4.2300	4.2300
	Public Policy	G.3.1	0.1775	0.1775	0.0000	0.1900	0.0000	0.0000	0.1825	0.1825	0.0000
		G.3.2	0.0000	0.0000	0.0000	0.7600	0.0000	0.7100	0.7300	0.7300	0.7300
		G.3.4	1.4600	1.4600	2.9600	1.5100	1.4600	1.4600	1.4800	1.4800	1.4800
Social	Employees	S.1.1	0.2825	0.2260	0.0000	0.0000	0.0000	0.0000	0.2800	0.0000	0.0000
		S.1.2	1.0650	1.0650	0.9375	2.1200	0.0000	0.0000	0.5300	1.0600	0.0000
		S.1.3	2.1300	2.1300	0.0000	1.0600	0.0000	0.0000	0.5300	0.0000	0.0000
		S.1.4	0.2825	0.2825	0.0000	0.0000	0.2825	0.0000	0.0000	0.0000	0.0000
		S.1.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		S.1.6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		S.1.7	4.9500	4.9500	6.0000	5.0000	5.0000	5.0000	5.0000	5.0000	5.0000
	Social Supply Chain	S.2.1	0.5650	0.2825	0.0000	0.0000	0.0000	0.0000	0.2850	0.0000	0.0000
		S.2.2	1.6300	1.6300	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		S.2.3	1.5000	1.5000	1.5000	1.5000	1.5000	1.5000	1.5000	1.5000	1.5000

	Customers	S.3.2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		S.3.3	4.7920	4.7920	4.7920	5.9900	5.9900	5.9900	5.9900	4.7920	5.9900
	Society & Community	S.4.1	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100
		S.4.3	3.2000	3.2000	4.0000	4.0000	4.0000	4.0000	3.2000	4.0000	3.2000
Environment	Operations Score	E.1.1	0.5000	0.5000	0.3750	0.2500	0.8200	0.0000	0.5000	0.1250	0.0000
		E.1.2	1.0000	0.8000	0.4000	0.8000	0.3280	0.0000	0.8000	0.8000	0.0000
		E.1.3	0.0000	0.0000	0.0000	0.0000	0.4100	0.0000	0.0000	0.0000	0.0000
		E.1.4	0.5000	0.5000	0.0000	0.5000	0.8200	0.5000	0.5000	0.5000	0.5000
		E.1.5	0.5000	0.5000	0.0000	0.5000	0.0000	0.0000	0.5000	0.5000	0.0000
		E.1.6	0.2500	0.2500	0.0000	0.5000	0.0000	0.2500	0.5000	0.5000	0.0000
		E.1.7	0.5000	0.5000	0.3750	0.5000	0.0000	0.0000	0.5000	0.5000	0.0000
		E.1.8	0.5000	0.1250	0.0000	0.1250	0.0000	0.0000	0.5000	0.0000	0.0000
		E.1.9	0.5000	0.5000	0.0000	0.5000	0.0000	0.2500	0.5000	0.5000	0.0000
		E.1.10	0.1250	0.2500	0.0000	0.0000	0.0000	0.2500	0.0000	0.0000	0.0000
		E.1.11	0.5000	0.0000	0.0000	0.5000	0.0000	0.0000	0.5000	0.0000	0.0000
		E.1.12	3.5000	3.5000	3.5000	3.5000	3.5000	3.5000	3.5000	3.5000	3.5000
	Environmental Supply Chain	E.2.1	1.2000	1.2000	0.0000	0.6000	0.0000	0.0000	1.2000	0.6000	0.0000
		E.2.2	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	Products & Services	E.3.2	4.0000	4.0000	5.0000	6.5400	5.0000	5.0000	5.0000	5.0000	5.0000

Appendix C:

		Banks			Diversified Financials			Insurance		
		Co. 1	**Co. 2**	**Co. 3**	**Co. 4**	**Co. 5**	**Co. 6**	**Co. 7**	**Co. 8**	**Co. 9**
Input		1	1	1	1	1	1	1	1	1
Output (Governance)	Business Ethics	8.09	5.69	9.71	10.716	9.0175	8.73	10.21	9.975	8.13
	Corporate Governance	10.76	8.958	9.13	8.1785	8.608	5.8	8.009	7.6	6.654
	Public Policy	1.6375	1.6375	2.96	2.46	1.46	2.17	2.3925	2.3925	2.21
Output (Social)	Employees	8.71	8.6535	6.9375	8.18	5.2825	5	6.34	6.06	5
	Social Supply Chain	3.695	3.4125	1.5	1.5	1.5	1.5	1.785	1.5	1.5
	Customers	4.792	4.792	4.792	5.99	5.99	5.99	5.99	4.792	5.99
	Society & Community	3.21	3.21	4.01	4.01	4.01	4.01	3.21	4.01	3.21
Output (Environment)	Operations Score	8.375	7.425	4.65	7.675	5.878	4.75	8.3	6.925	4
	Environmental Supply Chain	2.2	2.2	1	1.6	1	1	2.2	1.6	1
	Products & Services	4	4	5	6.54	5	5	5	5	5