EVALUATING RELATIVE OPERATIONAL PERFORMANCE OF FIRMS ON SUSTAINABILITY METRICS USING MULTI-LEVEL MULTI ATTRIBUTE DECISION MAKING (MADM)

By
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A Thesis Submitted to the Faculty of Graduate Studies of
The University of Manitoba
in partial fulfilment of the requirements of the degree of

MASTER OF SCIENCE

Faculty of Management
Department of Supply Chain Management
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Winnipeg

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CERTIFICATE

This is to certify that this thesis entitled "**Evaluating Relative Operational Performance of Firms on Sustainability Metrics using Multi-Level Multi Attribute Decision Making (MADM)**"submitted to the Department of Supply Chain Management, I. H. Asper School of Business, University of Manitoba, Winnipeg, ,Manitoba, Canada in fulfillment of the requirement for the award of the degree of Master of Science in Supply Chain Management by Mr. Rajdeep Singh Walia has been completed under my supervision and guidance.

To the best of my knowledge, this thesis contains original research work and that no part of this thesis has been submitted to this university or in any other university for any degree. This thesis is worthy of consideration for the award of degree of Master of Science in Supply Chain Management.

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DECLARATION

I, Rajdeep Singh Walia**,** declare that the thesis entitled "**Evaluating Relative Operational Performance of Firms on Sustainability Metrics using Multi-Level Multi Attribute Decision Making (MADM)"**submitted in the Department of Supply Chain Management, I. H. Asper School of Business, University of Manitoba, Winnipeg, Manitoba, Canada, is the original work of research carried out by me under the supervision and guidance of Dr. S.S. Appadoo in fulfillment of the requirement for the award of the degree of Master of Science in Supply Chain Management.

The works of authors consulted for this research work has been duly acknowledged in the thesis. To the best of my knowledge, no part of this thesis has been submitted to this university or in any other university for any degree.

Rajdeep Singh Walia

Place: Winnipeg, Manitoba, Canada

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ACKNOWLEDGEMENT

Completing a research work is not a simple thing; it’s a Herculean task and a team work requiring concerted efforts of many persons. The work of research is not complete without acknowledging the sincere efforts and co- operation of all those concerned. I wish to express my gratitude to all those who extended their valuable guidance and support in this study.

I am deeply indebted to my esteemed Supervisor, Dr. S.S. Appadoo, Head of the Department of Supply Chain Management, Asper School of Business, University of Manitoba, for his meticulous expert guidance throughout my research work. His constant support and advice made this study possible. He guided me through all the complexities involved in this research and always kept me on the right track. In spite of his busy academic as well as professional schedule of work, Dr. Appadoo has always spared his valuable time for me.

Furthermore, I am indebted to my Co-advisor Prof. Chhajju Bector for his valuable guidance, encouragement and support during the course of my research work. I would also like to thank the Advisory Committee members Dr.Yuvraj Gajpal and Prof. Saumen Mandal for their help and constant support. I am also obliged to Ms.Siobhan Vanderkee for her helpful attitude and cooperation.

Above all, I am grateful to the almighty God for giving me the spirit and strength to complete this work. And last but not the least I wish to express my gratitude to my parents, brother and family members who with their love and blessings always supported me in all endeavors.

Rajdeep Singh Walia

LIST OF ABBREVIATIONS AND ACRONYMS USED

Acronyms/ Abbreviations	**Full Forms**
AHP	Analytic Hierarchy Process
APA	American Psychological Association
API	American Petroleum Institute
BP	British Petroleum
CR	Consistency Ratio
CSI	Composite Sustainable Development
CSR	Corporate Social Responsibility
ELECTRE	Elimination and Choice Translating Reality
GHG	Green House Gas
IAOGP	International Association of Oil and Gas Producers
IOC	International Oil Company
IPIECA	International Petroleum Industry Environmental Conservation
ISO	International Standard Organization
KPI	Key Performance Indicator
MADM	Multi Attribute Decision Making
MCDM	Multi-level multi Criteria Decision Making
NIS	Negative Ideal Solution
NOC	National Oil Companies
ONGC	Oil and Natural Gas Corporation Limited
P/E	Price by Earning Ratio
PIS	Positive Ideal Solution
POC	Private Oil Companies
PROMETHEE	Preference Ranking Organization Method for Enrichment Evaluation
RI	Random Index

SAW	Simple Additive Weighting
SD	Sustainable Development
SIC	Standard Industry Classifications
SIF	Social Investment Forum
SME	Subject Matter Expert
SRI	Socially Responsible Investing
TBL	Triple Bottom Line
TOPSIS	Technique for Order Performance by Similarity to Ideal Solution
WBCSD	World Business Council for Sustainable Development
WCED	World Conference on Environmental Development

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ABSTRACT

Investors, stock exchanges and financial regulatory institutions can be used as strong levers for making firms accountable for achieving sustainable operational performance and not just maximizing profits. The objective of this research study is to enhance the quantitative tools available to stakeholders for evaluating relative operational performance of firms, thereby encouraging the financial investors to base their portfolio investment decisions on the basis of sustainable operational performance of firms. The study reviews the existing literature on evaluating relative operational performance of firms on sustainability metrics and proposes multi-level multi criteria decision making (MCDM) quantitative methods for measuring the same. The research work demonstrates the research framework proposed in the study by evaluating the 2014 Sustainable Operational Performance of firms in the oil & gas sector. The reason for choosing the oil & gas sector for this case study is in view of the relative large ecological and social impact which this industry has on different stakeholders. Due to the same reasons, the oil & gas sector is a bit more advanced in terms of its sustainability performance reporting standards. The review of past literature and the sustainability reports of firms for the year 2014 is initially used to develop the construct for measuring the firm operational performance on three pillars of TBL i.e. for the ecological, social and economic dimensions.

Keywords: Multi-Level AHP, TOPSIS, Sustainable Operational Performance Measurement, Oil & Gas Sector

CHAPTER-I

INTRODUCTION

1. Background

Sustainability recognizes the interdependence of ecological, social, and financial systems – the three pillars of operational performance. Corporate Social Responsibility (CSR) advocates ethical actions with respect to these dimensions(Hutchins and Sutherland 2008). This interpretation of sustainable development has led to the concept of Triple Bottom Line (TBL) which is a function of the three pillars of sustainable development i.e. economic, social and environmental (Clift 2004). Traditional financial reporting by publicly listed firms has been based on the notion, that although a firm is responsible for a number of identifiable distinct stakeholder groups, the primary concern of a firm is to meet the expectations of shareholders, prospective investors and financial lending institutions(FEE 2000). The various stakeholders have consistently voiced their concern that financial metrics alone do not represent true firm value (Asaolu, Agboola et al. 2012) . Post the 2009 financial crisis, investors have begun to acknowledge that traditional annual reports alone do not provide a full measure of business performance and new value creation. However in the last decade, firms have begun to face increasing pressure from regulatory institutions, investors groups, not for profit social & environmental groups for public disclosure of information regarding the firm operational performance on environmental and social metrics, in addition to the financial annual reports they currently publish (Brown 2000).

Similar to the historical origins of financial information disclosure wherein markets began to reward firms who outperformed their peers on financial indicators, in the coming years investor groups will move from just using financial metric performance measures to a more holistic firm performance metric system, for identifying which firms to invest in. This transition will be driven by the need of the firms to have a long term stable physical environment in which they can operate so as to maximize their operational and financial performance. Production halts due to labor union strikes or raw material stock outs due to social unrest in communities in which the firms or their suppliers have their assets results in loss of sales for the firms. Thus it is clear that the nature of a firm's operations has an impact on the communities and environment in which they operate and eventually this determines the future growth potential of the firm from a "perpetual going concern/ solvency "outlook. Innovest, a Risk-metrics group firm analyses firm performance on environmental, social and strategic criteria to identify risks and value blocks for potential investors by evaluating differentials which are not associated with conventional securities analysis (Delmas and Blass 2010). Socially Responsible Investing (SRI) which is defined as an " investment process that uses criteria based on environmental and social preferences to select or avoid investing in firms " (Renneboog, Ter Horst et al. 2008, Delmas and Blass 2010) is slowly gaining traction among hedge fund /mutual fund managers. Moreover since the late 1990's there has been a remarkable increase in sustainability reporting by multinational firms with one third of those reports being externally verified (Kolk 2003). The sustainability reports ensure the availability of data for making comparative assessments of firm performance on social, environmental and financial parameters. These three dimensions of firm performance constitute Triple Bottom Line (TBL) (Elkington 2004).

2. Statement of the Problem

Currently, most of the potential investors still select firms to invest in, primarily on the basis of the firm financial performance and not on the Triple Bottom Line or sustainability metrics. The Social Investment Forum (SIF) estimated that in 2007 only about 11 percent of the assets under professional management in the United States were invested with social responsibility in consideration. While the primary reason for this approach is the different level of preferences which each fund has for any of the three sustainability metric dimensions thereby resulting in the investors arriving at disparate results while assessing the same firm performance, another reason for lower popularity of SRI is the lack of acceptable quantitative tools for evaluating the relative performance metrics of firms on the three pillars of TBL.

In the last few years significant progress has been made in terms of development and acceptance of global standards such as GRI, Global Compact etc. for measuring firm operational performance on social and environmental standard. The literature detailing the conceptual frameworks or models which could be used as evaluation criteria for “measuring the sustainability performance of the firms” is quite limited. This results in a lack of transparency regarding the metrics used for evaluating firm social and environmental performance and thus investors shy away from considering TBL as a viable alternative investment evaluation framework (Delmas and Blass 2010). In 2008 Department of Labor of the US government issued a policy discouraging the trustees of pension plans to choose stocks while taking into consideration social, environmental and governance dimensions of firms. The decision was an acknowledgement of the scope of human subjective intervention which is currently prevalent in SRI thereby reducing the faith in firm TBL evaluation methods. It was recognized that a standardized approach similar to financial metrics (Net profit, return on equity, P/E) was needed for measuring metrics for comparing firm performance on environmental and social dimensions(Delmas and Blass 2010).

The next barrier which needs to be overcome is the need to have a wide choice of quantitative tools which can be used by hedge fund managers and portfolio analysts for identifying which stocks to choose for their portfolio investments without impacting the risk-return reward which is associated with a conventional approach which focuses only on firm financial performance. It is in this context that this research study aims to review the existing literature on different quantitative tools which are available for assessing sustainable performance of different firms and then subsequently aims to utilize the multi-level multi criteria decision making (MCDM) methods such as nested Analytic hierarchy process (AHP), SCORE and TOPSIS based models to evaluate the 2014 sustainability performance of selected oil & gas firms. The case study output results would demonstrate the Positive Screening methods which can be employed by investors/analysts for identifying the best performing firm on the chosen criteria for TBL. The research study has been conducted to:

a. Demonstrate the ability to leverage Socially Responsible Investing for driving Sustainable Firm Operational Performance

b. Enhance the availability of quantitative tools for measuring relative firm sustainable operational performance

c. Highlight the need for building a consensus based Industry Opinion regarding individual operational performance criteria weights

3. Significance of the Study

The three major contributions of the study towards management science academic literature and real world practical applications are:

a. Propounding Generic Principles for creation of Pairwise Comparison Matrix from underlying absolute secondary data units for Analytic Hierarchy Process method.

b. Development of MADM based quantitative tools for measuring relative firm operational performance on sustainability metrics.

c. Testing the presence of null/significance hypotheses for trends in firm operational performance for oil & gas sector firms.

4. Scope of Research Study

The research framework based on different MCDM quantitative techniques proposed in the research study can be applied for ranking the relative operational performance of the firms in any industry. The study demonstrates the application of these techniques by ranking the 2014 relative sustainable operational performance of 11 firms belonging to the SIC, industrial classification code 1311, crude petroleum and natural gas. The data for the firms has been aggregated from the 2014 sustainability reports published by the various firms (BP 2014, Shell 2014, Chevron 2014) .

In this research study the oil & gas sector has been chosen for demonstrating the case study as it is a unique sector where the firm operational performance is clearly reflected as a function of social, environmental and financial parameters. The enhanced focus on TBL by oil & gas firms is mainly due to the existing regulatory considerations in this sector as well as the greater link between the operational activities of an oil & gas firm and its surrounding social and physical environment. Due to increasing regulations, the global focus on developing cleaner sources of energy and pressure from different stakeholder groups; global energy majors have invested a lot of capital in developing cleaner sources of energy and making their operations more sustainable(IEA 2012). Moreover, in view of the increasing scrutiny faced by the energy sector, most of the oil & gas sector firms aim to be transparent about their operational activities. Thus in the last decade each of the major firms in this sector have published their performance on the three pillars of TBL in their annual sustainability reports. Lastly even while internally assessing their annual operational performance most of the energy firms have developed a holistic scorecard which incorporates operational, financial and environmental parameters such as total oil equivalent production (barrels), downstream profits, relative firm operational performance, environmental performance etc. This scorecard is used as the benchmark for arriving at the overall business performance score of the firm and impacts the annual variable salary of the firm employees.

5. Organizational Structure of Research Study

The research study is organized into 5 Chapters. Chapter I provides Introduction, Statement of the Problem, Significance, Objectives and Scope of the research study. In Chapter II, the literature on sustainable supply chain, the established sustainability metric performance reporting standards and some of the existing quantitative tools used for Socially Responsible Investing have been reviewed. In this Section, the multi criteria decision making methods (MCDM) like Analytic Hierarchy Process (AHP) and Technique for Order Performance by Similarity to Ideal Solution(TOPSIS) techniques have also been reviewed. After structuring the sustainable operational performance problem in Chapter II the emphasis shifts to developing the overall model and the proposed framework for evaluating relative operational performance of firms on sustainability metrics in Chapter III. This Section also describes the proposed principles for mapping of absolute firm operational performance metric values into priority ranking scores. These principles for generation of priority ratio scales can be used for generating any AHP priority matrix. These principles help to improve the underlying analytic hierarchy process technique by converting the absolute data points for different alternatives into Saaty's pairwise comparison matrix.

In Chapter IV, the proposed MCDM quantitative methods for measuring the relative sustainable performance of the firms on environmental, economic and social criteria have been illustrated using the 2014 operational performance data of 11 oil and gas sector firms. Finally, the last Section provides conclusions and discusses some of the limitations/trade-offs of adopting the multi criteria decision making methods for SRI.

6. Standard used for Citation

The citation standard used for giving citations and references is American Psychological Association (APA), 6th edition of Publication Manual of the American Psychological Association. References are given at the end of the study.

CHAPTER-II

REVIEW OF LITERATURE

1. Supply Chain Sustainability

Concurrent with the increasing realization of the significant impact which human activities impose on the ecological footprint of the globe, the concepts of sustainability and supply chain sustainability have gained a lot of traction during the past three decades. The transition of sustainability from a set of the technical concepts into the political and business mainstream is commonly linked to the book Our Common Future, also known as the Brundtland Report (WCED, 1987). The report described sustainable development as meeting “the needs of the present without compromising the ability of the future generations to meet their needs” (Brundtland, Khalid et al. 1987). The application of the concept of sustainability to firms is defined by the term business sustainability. The consulting firm Deloitte defines business sustainability as “adopting business strategies and activities that meet the needs of the enterprise and its stakeholders today while protecting, sustaining and enhancing the human and natural resources that will be needed in the future” (Deloitte andTouche 1992).

Over time application of business sustainability throughout the supply chain has come to be defined as sustainable supply chain management. For the purpose of this study I have adopted the definition for sustainable supply chain management given by Seuring and Muller which defines it as the management of material, information and capital flows as well as cooperation among the different firms involved in the supply chain in order to maximize the defined goals for all the three dimensions of sustainable development i.e economic, social and environmental (Seuring and Müller 2008) .

2. Socially Responsible Investment

Socially Responsible Investment (SRI) has grown significantly over the last decade and has increasingly been adopted by mainstream investment funds. Factors such as ethical consumerism, awareness about environmental impact and labor practices have resulted in a strong growth in the SRI industry over the past three decades (Renneboog, Ter Horst et al. 2008). In addition to financial firm performance, SRI investors base their investment decisions on different types of non- financial screen factors (Renneboog, Ter Horst et al. 2008, Renneboog, Ter Horst et al. 2011). A brief review of the major SRI funds investing principles highlighted in Table 2.1, indicates the importance of being able to quantify the non-financial performance factors and incorporate them in the investment decision process of fund managers.

TABLE 2.1: **SRI INVESTMENT FUNDS**

Socially Responsible Investing Fund	Investing Principle	Desired Outcome of Investing Principle	Need for Quantitative Stock Selection Tool
Domini Social Equity Fund	Passive Policy focused on avoiding investment in companies which are disapproved due to not meeting environmental and social standards Diversified Quantitative stock selection approach	Negative Screening/Avoidance approach to keep the investment portfolio clean and attain comparable long term rate of return	Yes
Interfaith Center on Corporate Responsibility	Forum of different church investors, thus no single coherent policy adopted. Focus on Shareholder resolutions to encourage firms to focus on holistic operational performance so as to maximize TBL	Encourage firms to focus on social, environmental and economic sustainability	No

Socially Responsible Investing Fund	Investing Principle	Desired Outcome of Investing Principle	Need for Quantitative Stock Selection Tool
Dow Jones Sustainability Index	RobecoSAM Corporate Sustainability Assessment survey used to evaluate companies on industry specific and general criteria on the 3 parameters of TBL	Selection of companies to be deemed eligible for listing on Dow Jones Sustainability Index and categorization of companies into : - Sector Leader - Sector Mover - SAM Gold Class/Silver Class/Bronze Class	Yes

All the three major SRI funds primarily utilize negative screening methods for making a relative evaluation of firm operational performance on sustainability metrics. Moreover, in the case of Dow Jones Sustainability Index the opinion of the firm managers for rating their annual operational performance on sustainability metrics is also taken into consideration. This can lead to a personal bias in the evaluation process. Also as all of these funds are competing in the open market hence they are reluctant to share the exact proprietary quantitative methods which they use for choosing their stock portfolio.

In view of the above highlighted reasons, it is very much evident that there is a substantial need for providing the various stakeholders such as government regulatory bodies, civil society & environmental organizations and investor community with better quantitative tools which can aid them in the decision making process of comparing firms on sustainable operational performance metrics.

3. Sustainability Performance Metric Framework

Over the past three decades, the development of global standards for measuring sustainability performance has helped to narrow down the differences among different stakeholders on the most relevant metrics for measuring social, environmental and financial dimensions of firm performance. Global Reporting Initiative, ISO 14031, the Global Compact , WBCSD efficiency Metrics and ICC Business Charter for Sustainable Development are the most commonly used standards for identifying the criteria for measuring TBL performance for different industries (Keeble, Topiol et al. 2003). Global Reporting Initiative aims to "enhance the quality, rigor and utility of sustainability reporting" (Initiative 2006). It uses a hierarchical framework in three focus areas, namely social, economic, and environmental. The framework includes categories, dimensions and more than 100 different indicators (Labuschagne, Brent et al. 2005) . Due to its hierarchical structure this standard has been widely used as the base framework for identifying the sub criteria for each of the pillars of TBL in previous research studies. Fig 1 describes the framework in greater detail. (Labuschagne, Brent et al., 2005)

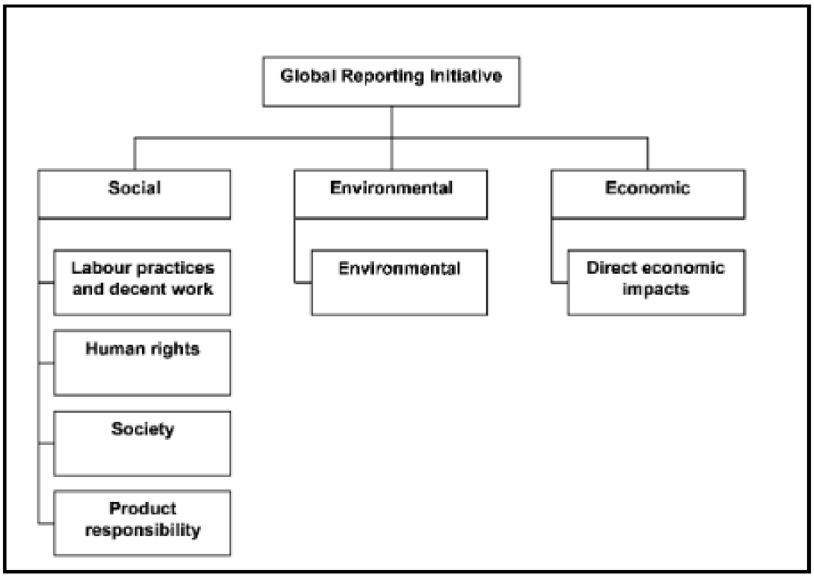

FIGURE 1: **THE HIERARCHICAL STRUCTURE OF THE GLOBAL REPORTING INITIATIVE FRAMEWORK**

3.1 Oil & Gas Sustainability Reporting Standard

In line with the GRI framework the oil and gas industry also recognized the need for firms to report on the sustainable operational performance dimensions and impacts to their key stakeholders on a periodical basis. In view of this, the key industry bodies i.e. the International Petroleum Industry Environmental Conservation Association (IPIECA), the International Association of Oil and Gas Producers (IAOGP) and the American Petroleum Institute (API) formed the Sustainability Reporting Initiative4 and published a guidance document on sustainability reporting in 2002 (IPIECA/API 2002, Guenther, Hoppe et al. 2006). The Sustainability Reporting Initiative4 lists down the sustainability performance metric indicators which oil & gas firms should report. These indicators are classified into three categories namely (a) Environmental Indicators (b) Health & Safety Performance Indicators and (c) Social & Economic Indicators. The detailed list of these indicators is listed in Table 4.5, 4.6 and 4.7 in Chapter IV of the research study.

The industry is still in the process of reaching an alignment on the quantitative measures which should be used for each performance indicator. Thus in the research study while developing the Oil & Gas Sector Sustainable Operational Performance Index a preference is given for those metrics for which a singular quantitative measure is used by majority of the firms for reporting the data. The filter criteria are explained in further detail in Chapter IV of the research study.

4. Multi Attribute Decision Making Techniques

MADM is a methodology which provides a structured framework for modelling real world problems where the decision maker is faced with making preference decisions between a set of viable alternatives on the basis of multiple conflicting attributes(Yoon and Hwang 1995, Mollaghasemi and Pet-Edwards 1997, Appadoo, Bhatt et al. 2012). One of the key characteristics of MADM is that it seeks to integrate objective measurement with value judgement and thus tries to manage subjectivity (Belton and Stewart 2002). MADM framework cannot be applied in optimization problems as like all decision making frameworks MADM does not remove subjectivity but instead tries to make the subjective preferences in the decision making problem explicit, rational and efficient (Hobbs and Meier 2012).

MADM methodology can be applied to problems which reflect the following characteristics: (a) decision makers need to choose from finite number of alternatives, (b) alternatives are evaluated on multiple attributes, (c) performance rating of each of the alternatives for each of the attributes can be reflected in measurable units, (d) decision makers can assign weights for each attribute as per their subjective preferences (Appadoo, Bhatt et al. 2012). Multi attribute decision making (MADM) have become hugely popular in the sphere of sustainable management due to their ability to provide solutions for problems which involve multiple objectives (Pohekar and Ramachandran 2004) . There are multiple MADM methods which can be employed such as weighted sum method, weighted product method, AHP, Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE), the Elimination and Choice Translating Reality (ELECTRE), Technique for Order Preference by Similarity to Ideal Solutions (TOPSIS).

MADM methods are based on statistical data for attributes for different alternatives $A_i(i = 1,2, \dots., n)$. The different attributes are assigned weights or significances $w_j(j = 1,2, \dots., m)$ on the basis of expert estimates. In MADM methods the evaluation aims at ranking the alternatives A_i by using quantitative multi criteria methods (Podvezko 2009). Similarly, Socially Responsible Investment can be defined as a multi-attribute stock selection problem wherein the analysts build their stock portfolio by choosing firms on the basis of a relative comparison of firm operational performance on TBL. Thus the primary research question of this study is to rank firms on the basis of relative operational performance on sustainability metrics using multiple MADM methods.

Pohekar et al. in their literature review paper in 2004 focused on trends in research studies published after 1970 which were multi criteria decision making problems. Their review indicates that Analytic Hierarchy Process(AHP) is one of the most popular technique employed for solving such problems (Pohekar and Ramachandran 2004) . AHP uses relative values and can be used in single or multi- dimensional decision making problems (Triantaphyllou 2000) . However, AHP's application in practical multi attribute decision making problems has been restrained by the human capacity for information processing or more precisely the human ability to generate consistent pairwise comparison matrices between different alternatives for each attribute(Shih, Shyur et al. 2007) . The other major MADM method which has been widely used for real world problems is the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). TOPSIS is based on the concept of distance measures of the alternatives from the positive ideal solution (PIS) and negative ideal solution (NIS). It thus reduces the requirement of pairwise comparisons and the inconsistencies generated due to human ability in generating the same (Shih, Shyur et al. 2007).

In the research study we develop two models for solving the primary research question using the two MADM methods AHP and TOPSIS respectively. Moreover, principles for creation of consistent pairwise matrices for alternatives for each criterion from underlying absolute unit data for each alternative are also proposed in the research study. The proposed principles eliminate the major limitation of applying AHP in real world MADM problems i.e limited number of alternatives. We demonstrate the two models by choosing a case study wherein we aim to rank the oil & gas firms on the basis of TBL operational performance metrics for the year 2014. Furthermore, post the introduction of principles for pairwise matrix generation in AHP, a comparison of the two MADM based models with a simple SCORE based SRI model is also discussed in the subsequent Chapter.

4.1 Methodology Based on Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process has been utilized in operations management area for years. It plays a vital role in decision making processing (Subramanian and Ramanathan 2012) by providing objective and reliable results, the multi-criteria decision-making environment in particular. This method has been used in many area, including the energy sector (San Cristóbal 2011). It can transfer a multidimensional problem into a one dimensional problem (Saaty 1988).

AHP is a systemic decision making framework that was originally proposed by Saaty (Saaty 1980). In AHP framework, comparison of the relative importance or preference of a parameter (objective or criterion) with respect to other parameters is based on pairwise comparison (Hossaini, Reza et al. 2015). By applying pairwise comparisons, AHP provides a mathematical solution, in order to determine weights and priority index, as compared to other weighting methods where weights are assigned arbitrarily (Reza, Sadiq et al. 2011). AHP has been studied by many scholars since 1986 when it was first reviewed by Zahedi. The most significant characteristic of AHP is that it mixes both qualitative and quantitative dimensions of a research problem (Subramanian & Ramanathan, 2012). Gonzalez et al. (2007) focused on integrating the concepts of AHP with genetic algorithms. They organized it into three basic principles: the hierarchy construction principle, the priority setting principle and the logical consistency principle. Normally, the first and the most important step in AHP is selecting the attributes, and these elements are arranged at the top of the hierarchy, the lower levels of elements represent the sub-attributes of the top attribute. The next step is estimating the relative weight by using "eigenvalue" method". The last step is testing for consistency of the pairwise comparisons(Zahedi 1986).

The AHP methodology is based on the generation of pairwise comparison matrix $P = ||p_{ij}||\ (i, j = 1,2, \ldots\ldots m)$ by the subject matter experts (Podvezko 2009).The attributes $R_i\ and\ R_j$ (i,j=1,2,….,m) are compared in the pairwise matrix, where m is the number of attributes being considered. The pairwise matrix can be mathematically represented which is as follow:

$$P = \begin{matrix} p_{11} & p_{12} \ldots\ldots & p_{1m} \\ p_{21} & p_{22} \ldots\ldots & p_{2m} \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ p_{m1} & p_{m2} \ldots\ldots & p_{mn} \end{matrix} = \begin{matrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} \ldots\ldots & \frac{w_1}{w_m} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} \ldots\ldots & \frac{w_2}{w_m} \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \frac{w_m}{w_1} & \frac{w_m}{w_2} \ldots\ldots & \frac{w_m}{w_m} \end{matrix} \quad \ldots\ldots..(1)$$

The detailed procedure for AHP is described as follows(Zahedi 1986):

a. Break the problem into a hierarchy of macro optimum goal, (sub) attributes, and alternatives.

b. Collect basic input data for all (sub) attributes and alternatives to make pairwise comparisons.

c. Evaluate the relative weights of each sub-criterion. A measure of importance used for pairwise comparisons is provided in Table 2.2 (Saaty 1988). According to the intensity scale, the expert is able to generate pairwise comparisons among sub-criteria and subsequently derive the relative importance of the factor

d. Aggregate weights and scores to establish a ranking of alternatives. The aggregated score is in the range of [0-1]. The alternative with the maximum value will be considered as a preferred alternative.

e. Perform sensitivity analysis to check the reliability and validity of the data.

The biggest advantage of AHP in comparison to other MADM methods is that it is not complicated since it is easier to compare the criteria in pairs than all at a time. The technique allows the qualitative estimates to be transformed to quantitative ones (Podvezko 2009). Table 2.2 presents the fundamental scale for developing priority matrix **(Saaty 1990)**

TABLE 2.2: FUNDAMENTAL SCALE FOR DEVELOPING PRIORITY MATRIX

Intensity of Importance	Definition	Explanation
1	Equally Strong	Two attributes/alternatives contribute equally to the objective
3	Moderately Strong	Experience and judgement slightly favor one attribute/alternative over another
5	Strong	Experience and judgement strongly favor one attribute/alternative over another
7	Very Strong	An attribute/alternative is favored very strongly over another, its dominance demonstrated in practice
9	Extremely Strong	The evidence favoring one attribute/alternative over another is of the highest possible order of affirmation

In this research study, the above ratings for measuring the relative firm operational performance have been adopted as part of the proposed evaluation framework. Based on the reliability testing method summarized by Aguilar-Lasserre et al. (2009), the consistency of the relative weights assigned to the elements in the pairwise matrix can be calculated by consistency ratio (CR) as follow:

$$CR = \frac{\frac{\lambda_{min} - n}{n-1}}{RI} \ldots\ldots (2)$$

, where λ_{max} represents the largest eigenvalue, *n* is the trace of the pairwise matrix, RI is a fixed number and changed with *n(Wind and Saaty 1980)*.This formula assesses the consistency of each expert's estimates. The value of consistency ratio (CR) which is <= 0.1 is considered to be acceptable implying that the matrix P is consistent. The matrix P defined above in equation (1) is said to be consistent if from the minimal amount of its elements all other elements can be obtained. The elements of the columns (and rows) of a consistent matrix will be proportional (Podvezko 2009). In this research study, the values of random consistency index (RI) stated by Podvezko in his paper" Application of AHP technique "in 2009 have been used for calculating RI. The same is described in Table 2.3.

TABLE 2.3: THE VALUES OF RANDOM CONSISTENCY INDEX (RI)

Matrix Order	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

4.2 Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

TOPSIS is based on the principle that the most preferred alternative should have the shortest distance from the positive ideal solution (PIS) and the longest distance from the negative ideal solution (NIS) (Hwang and Yoon 1981, Yeh 2003). The biggest advantages of TOPSIS are (a) its computational efficiency and (b) ability to measure the relative performance of alternatives for a given attribute without any upper ceiling on the number of alternatives which can be considered. For a multi-attribute decision making problem having n alternatives, j=1,2, …, n and m attributes, i=1,2, ….., m the TOPSIS method can be described as below:

- **Step 1**: Normalize the performance ratings of alternatives A_j $on\ attributes\ C_i\ by$

$$r_{ij} = \frac{x_{ij}}{\sqrt[2]{\sum_{j=1}^{n} x_{ij}^2}} \text{........... (3)}$$

- **Step 2**: For the weights $w_j \geq 0\ and\ \sum_{i=1}^{m} w_j = 1$, the normalized weighted ratings (y_{ij}) are as follows(Yeh 2003) :

$$y_{ij} = w_i r_{ij} \text{...... (4)}$$

- **Step 3**: Calculate PIS and NIS as below:

$$A^+ = (y_1^+, y_2^+, \dots \dots, y_m^+);\ A^- = (y_1^-, y_2^-, \dots \dots, y_m^-) \dots \dots \dots .. (5)$$

Where

$$y_i^+ = \begin{cases} max_j y_{ij} & if\ i\ is\ a\ benefit\ attribute \\ min_j y_{ij} & if\ i\ is\ a\ cost\ attribute \end{cases}$$

$$y_i^- = \begin{cases} min_j y_{ij} & if\ i\ is\ a\ benefit\ attribute \\ max_j y_{ij} & if\ i\ is\ a\ cost\ attribute \end{cases}$$

- **Step 4:** Determine the Euclidean distances between alternatives A_j and PIS($(D_j^+)\ and\ NIS\ (D_j^-)$:

$$D_j^+ = \sqrt{\sum_{i=1}^{m} (y_i^+ - y_{ij})2};\ \ D_j^- = \sqrt{\sum_{i=1}^{m} (y_i^- - y_{ij})2} \text{.......... (6)}$$

Where j= 1,2, …..., n

- **Step 5:** Overall performance value of each alternative is given by:

$$RC_j = \frac{D_j^-}{D_j^- + D_j^+}, \text{......... (7) where j = 1,2, ….., n}$$

CHAPTER-III

RESEARCH METHODOLOGY

1. Statement of Research Problem

As discussed in Chapter I, the research objective of this study is to enhance the availability of quantitative tools for evaluating relative firm operational performance on Sustainability Metrics. The research objective is a decision making problem wherein the preference needs to be made from a set of alternatives on the basis of multiple, even conflicting attributes. Thus the primary research question of this study can be explained as below:

Primary Research Question: “Rank firm operational performance on sustainability metrics using multiple MADM methods namely AHP, TOPSIS “.

Secondary Research Question: The case study demonstrated in the research study also analyzes the trends in operational performance of firms in the oil & gas sector. The hypotheses will be tested using statistical methods and are described as below:

H0: National Oil Companies perform equally well as International Oil Companies and Private Oil Companies on social performance indicators

H1: National Oil Companies do not perform similarly as International Oil Companies and Private Oil Companies on social performance indicators

H0’: International Oil Companies perform equally well as National Oil Companies on environmental performance indicators

H1’: International Oil Companies do not perform similar to National Oil Companies on environmental performance indicators

2. Literature Review of Relative Firm Operational Performance Measurement Framework

2.1 Composite Sustainable Performance Index

Krajnc and Glavic presented a framework in 2005 for developing a composite sustainable performance index in order to track integrated information of economic, environmental and social indicators on a time series basis. The framework of Krajnc and Glavic is as follow:

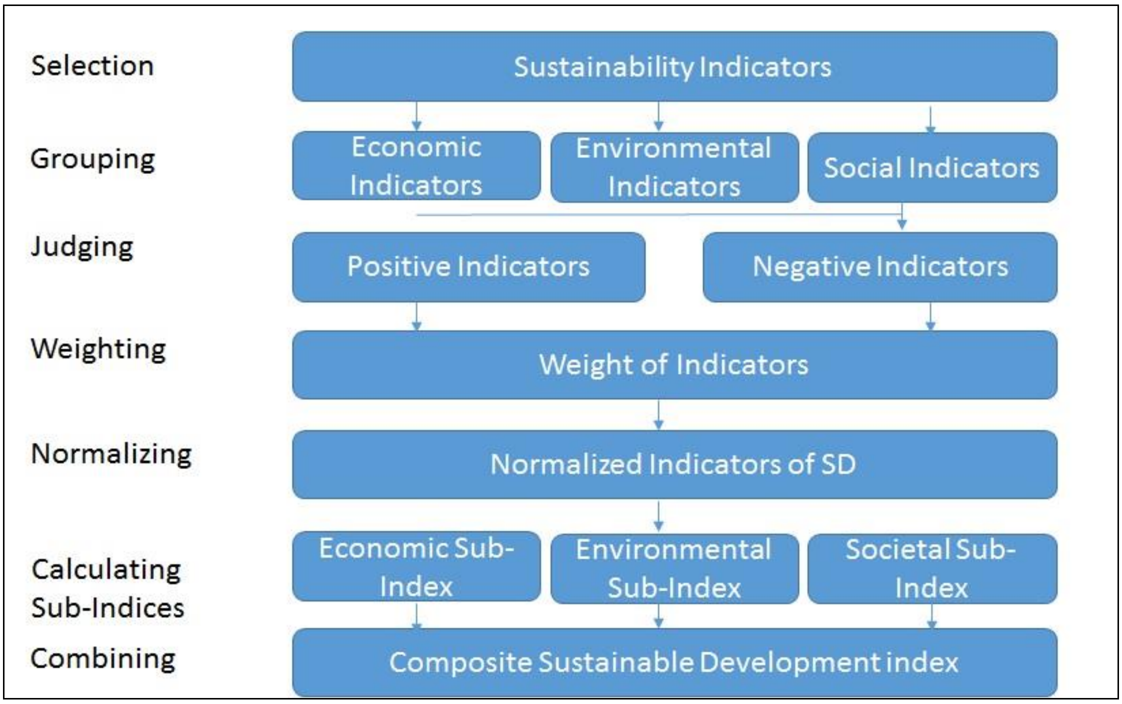

FIGURE 2: COMPOSITE SUSTAINABLE PERFORMANCE INDEX FRAMEWORK (Krajnc and Glavič 2005)

This framework which is primarily designed for analyzing a firm operational performance on sustainability metrics on a time-series basis holds a universal relevance for developing a hierarchical composite sustainable performance index for a firm. The third step of the framework i.e. “Judging” recommends the classification of the performance indicators into “Positive Indicators/ Benefit Attributes “and

“Negative Indicators /Cost Attributes “. I have adapted this framework specifically in terms of how the normalization of indicators should be implemented and incorporated the modified framework of Krajnc, Glavic in the upper module (“Selection of indicators”) of my proposed research framework.

2.2 Choice of Quantitative Method

MADM methods seem to be the ideal choice for solving the Socially Responsible Investment problem as it fulfills the traditional key characteristics of real world problems which have been solved by MADM. Table 3.1 highlights this fit:

TABLE 3.1: MADM CHARACTERISTICS OF SRI

MADM Characteristics	SRI Problem Attributes
Multiple Alternatives	**Different firms** which are being evaluated on operational performance sustainability metrics are the equivalent alternatives
Multiple Attributes	Economic, Social and Environmental Dimensions represent the top level of the attributes in the hierarchical sustainability index structure
Measurement of Attributes in Units	Each of the sub elements for the three top level attributes has a standard industry wide unit of measurement.

For example, if an industry regulator wants to evaluate the relative performance of firms in the oil and gas industry, then Table 3.1 reflects that the above use of MADM methods would be the best aid for him in this decision making problem. This is because firms like Royal Dutch Shell, Exxon Mobil, Total, Saudi Aramco etc. reflect the different alternatives which are under consideration. The MADM characteristic of multiple attributes is analogous to the sustainable operational performance metrics such as greenhouse gas emissions (GHG), net profit etc. Lastly oil & gas industry bodies such as The International Petroleum Industry Environmental Conservation Association (IPIECA), American Petroleum Institute (API) have developed sustainability standard for the oil & gas industry popularly known as Sustainability Reporting Initiative. This standard enumerates the units of measurements for the different sustainability indicators which should be used by all the firms while reporting data in their sustainability reports. Hence a framework which is based on MADM for solving the SRI problem has been proposed in this study.

3. Proposed Research Framework

The research framework proposed in the study is built on integrating a modified version of the Krajnc, Glavic Composite Sustainability Index framework with MADM quantitative processes for calculation of alternative preferences. As depicted in Figure 3 below, the upper two modules represent the modified version of the Earlier Composite Sustainability Index while the lower two modules represent the AHP quantitative process methods.

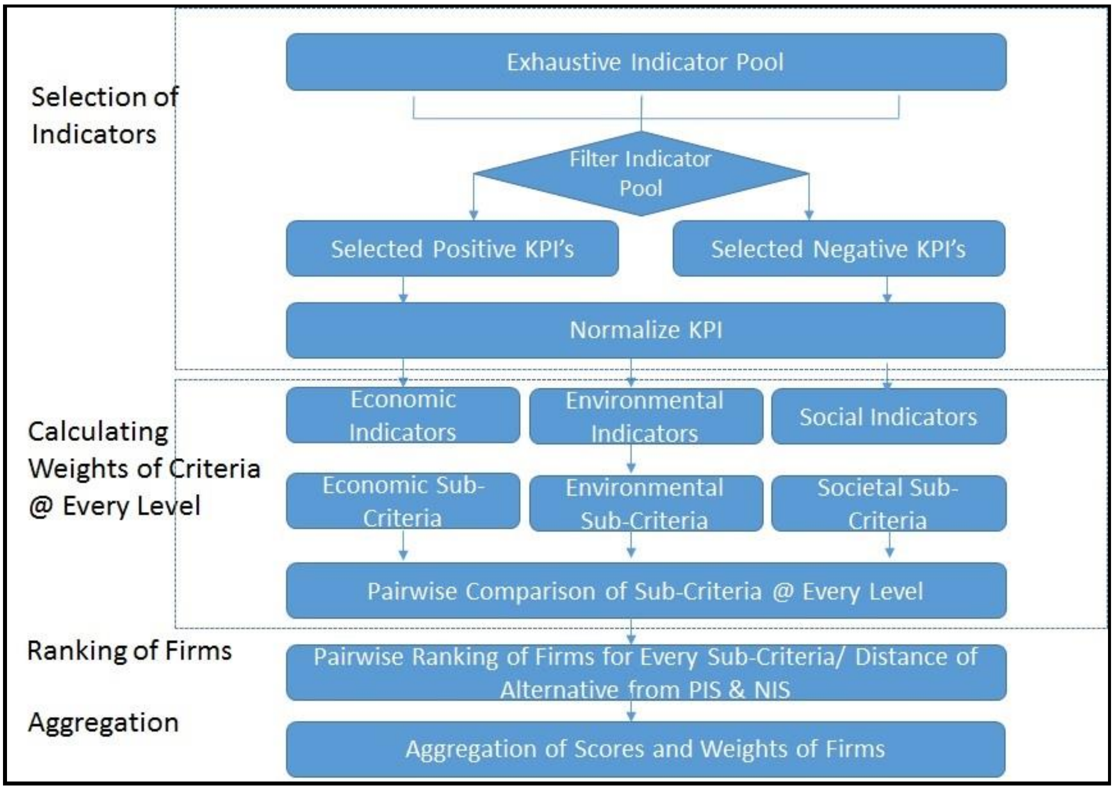

FIGURE 3: PROPOSED FRAMEWORK FOR EVALUATING RELATIVE FIRM SUSTAINABLE OPERATIONAL PERFORMANCE

3.1 Selection of Indicators

The framework for the proposed quantitative tool for evaluating firm sustainable operational performance for any sector begins by the development of the composite sustainable index for that sector. It requires the creation of an exhaustive set of sustainable operational performance metrics/indicators which are considered to be relevant for that sector. As discussed earlier most of the sector/industry associations in conjunction with the sector specific regulatory bodies have been able to propose a guideline/index which maps the sustainability indicators for that sector. Most of these indexes are based on the Global Reporting Initiative guidelines and they even go a step further by enumerating the sector specific indicators and the unit of measurement for each of the sustainability indicators. The set of Sector Sustainable Index Metrics can be developed by following the following steps:

i. Categorize each of the social, economic and environmental indicators into suitable sector specific categories. For example, the environmental indicators for Oil & Gas sector can be broadly categorized into categories such as “Waste Generation/Disposal”, “Energy Consumption”, “Water Consumption/Disposal”, “Biodiversity Impact “etc. Literature review and expert opinion are the recommended methods for identifying the categories.

ii. The sector experts while developing the sector hierarchical sustainable index need to ensure that suitable representation of indicators for each of the sub categories of environmental, social and environmental pillars of sustainability is attained.

iii. The filtered list of indicators in the sector sustainable index should be marked as "Positive Indicators/ Benefit Attributes "or "Negative Indicators/ Cost Attributes".

iv. Finally, the list of indicators need to be normalized in order to remove size or geography bias. For Example, in the oil and gas sector the equivalent derived indicators for GHG emissions and community contribution attained after normalization are " $\frac{GHG\ Emission}{Total\ Oil\ Equivalent\ Production}$", "$\frac{Community\ Contribution}{Net\ Profit}$".

3.2 Weightage of Indicators

After the creation of the sector sustainable operational performance measurement index, the next step is to identify the weights which need to be allocated to each of the metrics at every level of the sustainable operational performance index. The framework proposes the application of Multi- Level Analytic Hierarchy Process method for generation of pairwise matrix between the attributes/metrics at every level. The application of multi-level AHP systematic framework aids to convert the subjective assessment of relative weights (importance, likelihood, or preference) to a set of priority ratio scale and overall scores (Sadiq, Husain et al. 2003). For example, the decision matrix for a single hierarchy level problem having m number of attributes/indicators can be represented as:

$$W = \begin{bmatrix} p_{11} & p_{12\ldots\ldots} & p_{1m} \\ p_{21} & p_{22\ldots\ldots} & p_{2m} \\ . & . & . \\ . & . & . \\ p_{m1} & p_{m2\ldots\ldots} & p_{mm} \end{bmatrix}$$

Where p_{ij} refers to the preference of indicator "i" over indicator "j" as per Saaty's fundamental scale discussed in Table 2.2. This preference factor is a reflection of the relative importance of the two operational performance indicators with respect to each other in the overall firm sustainable operational performance index. In other words, it reflects the tradeoff which a firm needs to make in view of the necessity of firm operational performance being a function of multiple & conflicting objectives.

There are two key takeaways for the Multi-Level AHP method which need to be achieved at this stage:

i. The pairwise matrix needs to be generated for every level of hierarchy for each of the trees of the Sustainable Operational Performance Index.

ii. For a single tree with n levels of hierarchy and m attributes in the Sustainable Operational Performance Index, the following equations should hold true:

$\sum_{j=1}^{m_1} a_j = 1$, where m_i represents number of attributes at any given hierarchy level "i" and

$$\sum_{k=1}^{n} m_k = m$$

3.3 Ranking of Firms

Once the weights have been allocated to the different indicators/ performance metrics of operational performance by using a mutli-level AHP process, the next step in the proposed framework for the SRI problem solution requires the comparison of the different firms on the sustainable operational performance metrics. The framework proposes the application of MADM methods such as AHP, TOPSIS or Simple Additive Weighting (SAW) methods for achieving this objective. The reasons for proposing three different MADM methods is due to the relative novelty of applying MADM techniques for the SRI solution landscape. Thus it makes sense to initially provide the analysts and other stakeholders involved in this domain with multiple decision aid choices. Subsequently as the output results of these methods are applied in real world SRI decision making, the choice of the most suitable MADM method applicable for SRI problem should get narrowed down.

The reasons for integrating AHP and TOPSIS in comparison to other MADM methods as part of the SRI solution framework have already been discussed in detail in Section 4 of Chapter II. AHP traditionally suffers from its limitation of the maximum no of alternatives which it can consider while generating consistent pairwise comparisons. However as highlighted in the previous Section AHP is the most suitable MADM method for identifying the weights of different operational performance indicators, hence if the same method for the relative comparison of the firms is used, it reduces the burden on the analysts/practitioners to learn multiple quantitative methods.

Table 3.2 enumerates a brief comparison of AHP and TOPSIS, which are the two methods recommended for ranking of the firms in the proposed SRI framework.

TABLE 3.2: COMPARISON OF AHP AND TOPSIS

Parameters	**AHP**	**TOPSIS**
Core Principle	Pairwise Comparison	Ideal Solution from PIS And NIS
Weight allocation of attributes	Pairwise Comparison	Pre-requisite, needs to be given
Consistency Check Method	Provided	None
No. of attributes accommodated	10	Many more
No. of alternatives accommodated	10*	Many more

Source: Refer to (Hwang and Yoon 1981, Shih, Shyur et al. 2007)

* One of the biggest hurdles in the use of AHP is the maximum number of alternatives which can be accommodated using this method. In this research study, certain quantitative principles which help to map the absolute value of the alternatives for a given

criterion into the set of priority ratio scales of Saaty's pairwise comparison fundamental scale have been proposed. These general quantitative principles are limited not only for application in this existing research problem but instead the same can also be used for all MADM decision making problems wherein the practitioners have absolute value data for the different alternatives for each of the attributes under consideration.

Using these principles, consistent pairwise comparison matrix for any number of alternatives can be generated. The principles are discussed in the later Section in this Chapter and their utility is demonstrated through real time application of these principles in the case study discussed in the Chapter IV.

3.4 Aggregation of Scores

The last step in the evaluation of firms on sustainable operational performance using MADM methods is attained by means of a simple weighted sum of the indicators for each of the firms under consideration. It is an integration of Step 2, "Weights of indicators "and Step 3 "Ranking of Firms "which is summarized as below:

i. Identify the weights $\sum_{j=1}^{m} w_{j,}$of the m number of Indicators constituting the hierarchical Sustainable Operational Performance Index using multi-level AHP

ii. Identify the Firm Preference value for each of the indicators using either AHP or TOPSIS methods.

iii. Aggregate the scores using the simple weighted sum method. For example for a single level sustainable operational performance index having m number of indicators and n number of firms, the overall preference value of each alternative (V_i) is given by:

$V_i = \sum_{j=1}^{m} w_j \ r_{ij}$……… (8) , where r_{ij}represents the firm normalized rating for a given indicator.

4. Principles for Development of Priority Ratio Scales in AHP

One of the key requirements for ensuring a greater validity of the quantitative results i.e the ranking of the firms on sustainable operational performance metrics is to be able to map the absolute firm values for these metrics into Saaty's priority ratio scale.The key principles for mapping the absolute firm operational performance metric values into the set of priority ratio scale are described below:

a. For a +ve Indicator/Benefit

Attribute $i * j \ pairwise \ comparison \ matrix \begin{bmatrix} \mu_{11} & \mu_{12} & \mu_{13} \\ \mu_{21} & \mu_{22} & \mu_{23} \end{bmatrix}$

$$\mu_{ij} = \begin{cases} \frac{|(X_i - X_j)|}{\frac{|(X_{Max} - X_{min})|}{(K-1)}} + 1 & if X_i > X_j \\ \frac{1}{(\frac{|(X_j - X_i)|}{\frac{|(X_{Max} - X_{min})|}{(K-1)}} + 1)} & if X_i < X_j \\ 1 & if X_i = X_j \end{cases} \quad \ldots\ldots\ldots\ldots\ldots. (9)$$

b. For a –ve Indicator/ Cost

Attribute $i * j \ pairwise \ comparison \ matrix \begin{bmatrix} \mu_{11} & \mu_{12} & \mu_{13} \\ \mu_{21} & \mu_{22} & \mu_{23} \end{bmatrix}$

$$\mu_{ij} = \begin{cases} \frac{|(X_j - X_i)|}{\frac{|(X_{Max} - X_{min})|}{(K-1)}} + 1 & if X_i < X_j \\ \frac{1}{(\frac{|(X_i - X_j)|}{\frac{|(X_{Max} - X_{min})|}{(K-1)}} + 1)} & if X_i > X_j \\ 1 & if X_i = X_j \end{cases} \quad \ldots\ldots\ldots\ldots\ldots (10)$$

where K ∈

$\{2,3,4,5,6,7,8,9\}$, $X_i \ is \ i^{th} Firm \ value \ for \ the \ operational \ performance \ metric \ under$

$consideration, X_j \ is \ j^{th} \ Firm \ value \ for \ the \ operational \ performance \ metric \ under$

$consideration, X_{Max} \ is \ Max \ value \ for \ the \ operational \ performance \ metric \ under$

$consideration$from all the firms

$X_{Min} \ is \ Min \ value \ for \ the \ operational \ performance \ metric \ under \ consideration$ from all the firms

The value of K can be defined as any integer between the range of 2-9. The reason for defining the ceiling value of K equal to 9 is to ensure that the priority matrix generated post the mapping follows the fundamental scale of Saaty for AHP priority comparisons.

CHAPTER-IV

SUSTAINABLE OPERATIONAL PERFORMANCE OF OIL & GAS SECTOR FIRMS: A CASE STUDY

1. Introduction

In order to demonstrate the implementation of positive screening for SRI, i.e identifying the relative order of firms in which a socially responsible investor should invest using multi-level analytic hierarchy process (AHP) or TOPSIS methods, a representative case study based on the detailed analysis of the social, environmental and financial performance of 11 oil & gas sector firms has been presented in this research work. The firms for the case study were chosen on the basis of the following criteria:

- Firstly, the firms belong to the industrial classification code 1311 for crude, petroleum and natural gas
- Secondly, the firms chosen were publicly listed
- Lastly, those firms were selected which have published their sustainability reports for the annual year 2014.

Another point that needs to be emphasized is that although these firms belong to the same sector however there are slight differences between these companies, firstly in terms of the shareholder ownership structure of the firms and secondly in terms of the extent of global footprint of the firms. On the basis of the first criteria the firms can be classified as either national oil companies (NOC) or non-government controlled oil companies. Non-government controlled oil companies can be further classified into two categories on the basis of their extent of global reach. The non-government controlled oil companies which have majority of their operations present in just one nation are referred to as “private oil companies (POC) “while the second category is referred to as “international oil companies (IOC)”. Table 4.1 briefly shares the profile of the 11 firms which have been considered in the research study.

TABLE 4.1: DESCRIPTION OF FIRM PROFILE INCLUDED IN THE ANALYSIS (2014)

Name	Headquarter	Revenue (US$ bn)	Net Profit (US$ bn)	Operating Cash Flow (US$ bn)	Type of Firm
BP	London, UK	353.6	4.0	32.8	IOC
Chevron	San Ramon, California, USA	200.5	19.2	31.5	IOC
Shell	The Hague, Netherlands	421.0	14.7	45.0	IOC
Petrobras	Rio de Janeiro, Brazil	127.3	-8.2	26.6	NOC
ONGC	Dehradun, India	10.9	3.0	4.4	NOC
Repsol	Madrid, Spain	57.1	1.9	3.9	POC
Petronas	Kuala Lumpur, Malaysia	94.0	13.6	29.6	NOC
Total	Courbevoie, France	236.1	12.8	25.6	IOC
ExxonMobil	Irving, USA	394.1	32.5	45.1	IOC
Rosneft	Moscow, Russia	106.4	22.0	28.7	POC
Husky	Calgary, Canada	21.6	1.2	4.8	POC

*** Revenue and net profit converted to US$ using Dec31, 2014 currency rates**

2. Data Analysis of Firm Operational Performance for the year 2014

The operational performance data for the different firms which have been considered in the case study is for the 2014 financial year. Two different types of reports have been used for collection of the data of the different firms. Financial data has been collected from the 2014 Annual reports of the firms. In case of certain firms such as ONGC the annual financial year is April- March and not the traditional calendar year.

For such firms, the company defined financial year has been considered for the relevant data set for the purpose of the case study. The second type of reports which have been the source of secondary data for the environmental and social operational performance metrics of firms are the "2014 Company Sustainability Reports or Community Reports ". Most of the firms have published their annual sustainability operational performance data in these reports at an integrated firm level. Moreover, majority of the firms considered in the case study follow the IPIECA guidelines considerably while reporting the data in their annual Sustainability report. The secondary datasets for the 11 firms which have been considered in the case study are highlighted below in Tables 4.2, 4.3 and 4.4.

TABLE 4.2: FIRM FINANCIAL PERFORMANCE DATA FOR THE YEAR 2014

Firm Name	Total Hydrocarbons Produced (thousand Barrels of Oil Equivalent (mboe) per day)	Operating Cash Flow ($ billion)	Net Profit ($ billion)	Revenues($ billion)
BP	3151	32.8	4.0	353.6
Chevron	2571	31.5	19.2	200.5
Shell	3100	45.0	14.7	421.0
Petrobras	2670	26.6	-8.2	127.3
ONGC	1152	4.4	3.0	10.9
Repsol	559	3.9	1.9	57.1
Petronas	2226	29.6	13.6	94.0
Total	2100	25.6	12.8	236.1
ExxonMobil	4000	45.1	32.5	394.1
Rosneft	4279	28.7	22.0	106.4
Husky	340	4.8	1.2	21.6

TABLE 4.3: FIRM SOCIAL PERFORMANCE DATA FOR THE YEAR 2014

Firm Name	Gender Diversity	Fatalities-workforce	Recordable Injury Frequency (RIF) – Workforce (Incidents per 200,000 work-hours)	Contribution to Communities ($ million)	Community Contribution/Net profit
BP	22	3	0.31	85.0	21.2
Chevron	24.7	3	0.18	240.0	12.5
Shell	29	5	0.20	160.0	10.9
Petrobras*	16.8	10	0.97	231.0	51.6
ONGC	7	5	0.12	61.1	20.6
Repsol	33	0	0.48	31.5	16.5
Petronas	28	10	0.13	142.0	10.4
Total	31.1	9	0.22	610.0	47.7
ExxonMobil	28	3	0.26	279.5	8.6
Rosneft	34	37	0.07	141.3	6.4
Husky	25	0	0.80	4.3	3.5

*** Petrobras posted net loss for 2014 thus for normalization of "Community Contribution" by dividing it with the firm which posted the least "net profit"**

TABLE 4.4A: FIRM ENVIRONMENTAL PERFORMANCE DATA (OIL SPILLS) FOR THE YEAR 2014

Firm Name	Oil spills – to land and water (number)- Any spill which is greater than 159 litres is included	Volume of oil spilled (million litres)
BP	63	0.40
Chevron	79	0.13
Shell	153	0.90
Petrobras	32	0.07
ONGC	0	0.00
Repsol	17	0.38
Petronas	25	0.63
Total	129	5.80
ExxonMobil	336	1.45
Rosneft		1.09
Husky	327	0.00

TABLE 4.4B: FIRM ENVIRONMENTAL PERFORMANCE DATA (EMISSIONS) FOR THE YEAR 2014

Firm Name	Direct greenhouse gas (GHG) (MteCO2 equivalent (CO2))	Total SO2 emissions (thousand metric tons)	Total Nitrogen Oxides emissions (thousand metric tons)
BP	48.6	39	129
Chevron	56	113	139
Shell	76	97	146
Petrobras	79.1	133.46	299.28
ONGC	18.9	-	-
Repsol	13.8	29.8	35.40
Petronas	29.54	61.70	100.92
Total	44	65	93
ExxonMobil	114	100	140
Rosneft	49.8	58	49
Husky	11.26	7.80	9.02

TABLE 4.4C: FIRM ENVIRONMENTAL PERFORMANCE DATA (NATURAL RESOURCES) FOR THE YEAR 2014

Firm Name	Total Energy Consumption for operated assets and non-operated joint venture refineries (million gigajoules)	Hazardous Waste Disposed (kte)/thousand metric tons	Volume of FreshWater Withdrawn (mn cubic meters)
BP	799	165	280
Chevron	879	815	85
Shell	-	529	199
Petrobras	1160	245	206.5
ONGC	223.6	13.5	41.1
Repsol	178.4	66.43	54.7
Petronas	-	26.97	49.3
Total	550.8	223	112
ExxonMobil	1600	300	270
Rosneft	442.8	755	326.1
Husky	133.6	-	23.4

However, two limitations still exist in the data sets which have been considered for the case study. The same are discussed below in detail:

i. Firms have adopted different units of measurement for the same operational performance metric. Some of these units can be converted into equivalents units of measurement while in case of some operational performance metrics it is not possible to convert the data unit for all the firms into a standard unit of measurement. For example, for the environmental operational performance metric “Volume of oil spilled”, some of the oil & gas firms have published their 2014 data as per unit of measurement “mnltrs” while others have reported in the unit of measurement “barrels per annum”. For this metric the later unit of measurement has been converted to the former before analyzing the data. However, I would like to acknowledge that in spite of the researcher’s best efforts while standardizing the data sets, some discrepancies might have crept into the secondary data which has been considered for the case study. This does not impact the overall research study objectives as the purpose of the case study is to demonstrate the steps involved in the application of MCDM quantitative methods for relative firm performance measurement and not to critically analyze the 2014 sustainability operational performance of the oil & gas sector firms.

ii. The pairwise comparison matrix for the different levels of sustainable operational performance metrics is generated using the literature from (Krajnc and Glavič 2005) and the author’s understanding of the oil & gas industry. The recommended method is to carry out a survey of sector experts seeking their opinion on preferences for the relevant industry specific operational performance parameters. Using these results from the survey the AHP pairwise matrix for the different metrics at different levels of the sustainable operational performance index can be developed.

3. Application of MCDM Methods for Measuring Relative Firm Performance in O&G Sector

3.1 Selection of Indicators or Operational Performance Metrics

The sustainable operational performance metrics for oil & gas industry have been identified by the sector experts under the aegis of IPIECA, API and IOGP. The three institutions released the revised Sustainable Initiative4 guidelines in 2006 which lists the key operational performance metrics which oil & gas firms should publish in their annual sustainability reports. These oil and gas sector metrics have been based on the GRI standard for Sustainable Operational Performance. IPIECA lists the sustainable metrics under three major categories. The first category is referred to as “Social and Economic Indicators”, the second category is “Environmental Indicators” and the last category is referred to as “Health & Safety Indicators”.

The exhaustive list of sustainable metrics under each of the categories is shared in Table 4.5, 4.6 and 4.7 respectively. It needs to be pointed out here that, the metrics under the category “Health &Safety Indicators” are reclassified into the “Environmental metrics” and “Social Metrics dimensions for the purpose of this case study research.

TABLE 4.5: IPIECA ENVIRONMENTAL PERFORMANCE INDICATORS & MAPPING AGAINST GRI

Environmental Indicators	Disclosure	Significance of Indicator	Quantitative Measure Unit (Consensus)
Greenhouse Gas Emissions	Total direct greenhouse gas emissions	High	Yes
	Energy indirect greenhouse gas emissions	High	Yes
	Other indirect greenhouse gas emissions	Medium	Yes
	GHG emissions intensity ratio	Medium	No
	Initiatives to reduce greenhouse gas emissions and reductions achieved	High	No

Environmental Indicators	Disclosure	Significance of Indicator	Quantitative Measure Unit (Consensus)
Energy Use	Significant environmental impacts of transporting products and other goods & materials used for the organization's operations, and transporting members of the workforce	Low	No
	Energy consumption within the organization	High	Yes
	Energy Intensity Ratio	High	Yes
	Energy saved due to conservation and efficiency improvements	High	No
Alternative Energy Sources	Total amount invested in renewable energy	Medium	Yes
	Total amount of renewable energy generated by source	High	Yes
	Initiatives to provide energy efficient and renewable based products and reductions in energy reqts due to same	Medium	No
Other Air Emissions	Emissions of ozone depleting substances	High	Yes
	Nox, Sox and other air emissions	High	Yes
Spills	No and volume of spills	High	Yes
	Environmental impact of transporting goods and materials for use by firm	Low	No
Waste	% of materials used that are recycled	Low	No
	Total weight of waste by type and disposal method	High	Yes
	Total hazardous waste transported, generated and treated	Medium	Yes
	Amount of Drilling Waste	Medium	No
Decommissioning	No of sites that have been decommissioned	Medium	No

Source:(Boyle and Depraz 2006)

TABLE 4.6: IPIECA HEALTH & SAFETY PERFORMANCE INDICATORS AND MAPPING AGAINST GRI GUIDELINES

Health & Safety Performance Indicators	Disclosure	Significance of Indicator	Quantitative Measure Unit (Consensus)
Workforce Participation	Total % of workforce represented in joint worker management health & safety committees	High	Yes
	Health and safety topics covered in formal agreements with trade unions	High	No
Workforce Health	Workers with high incidence or high risk of illnesses due to occupational hazards	High	No
Occupational Injury	Types of injury and rates of injury, fatality, lost days and absenteeism	High	Yes

Source:(Boyle and Depraz 2006)

TABLE 4.7: IPIECA SOCIAL & ECONOMIC PERFORMANCE INDICATORS & MAPPING AGAINST GRI GUIDELINES

Social & Economic Indicators	Disclosure	Significance of Indicator	Quantitative Measure Unit (Consensus)
Indigenous People	Number of incidents of violations involving rights of indigenous people	Medium	No
	Case Studies highlighting firm operations which impact indigenous communities	High	No
Involuntary Resettlement	Operations where involuntary resettlement took place, no of households affected and how many were resettled	High	Yes
Social Investment	Direct economic value generated and distributed including infrastructure	High	Yes
Local Content Practices	% of procurement from local suppliers at major locations	High	Yes
Local Hiring Practices	% of senior management hired from local regions	High	Yes

Social & Economic Indicators	Disclosure	Significance of Indicator	Quantitative Measure Unit (Consensus)
Workforce Diversity and Inclusion	% of women , minorities as part of senior management	High	Yes
Preventing Corruption	Total no of questions assessed for risks related to corruption	High	No
	confirmed incidents of corruption and action taken	Medium	No
Preventing corruption involving business partners	% of business units analyzed for possible risks of corruption	High	No
	% of suppliers screened for criteria of impacts on society	Medium	No
Transparency of payments to host government	Direct economic value generated in terms of taxation paid	High	Yes
	Financial assistance received from government	Low	No
	Total value of political contributions	Medium	Yes
Public advocacy and lobbying	Total value of political contributions	Medium	Yes

Source:(Boyle and Depraz 2006)

This establishes the exhaustive indicator pools which have been listed above in Tables 4.5, 4.6 and 4.7. The indicator pool reflects a set of general and oil & gas industry specific criteria for TBL performance. The next step in the relative performance evaluation of firms for a given sector on sustainable operational performance involves the construction of the sustainable index by filtering the metrics from the exhaustive list of the sector specific sustainable operational performance indicator pool. The same is demonstrated by means of the Oil & Gas Sector. We follow the steps described in the proposed research framework in Section 3.2.1. It constitutes Step 1 of the proposed research framework and is an adapted version of the framework proposed by Krajnc, Glavic and Keeble et al. (2003). The same is summarized below in Figure 4.

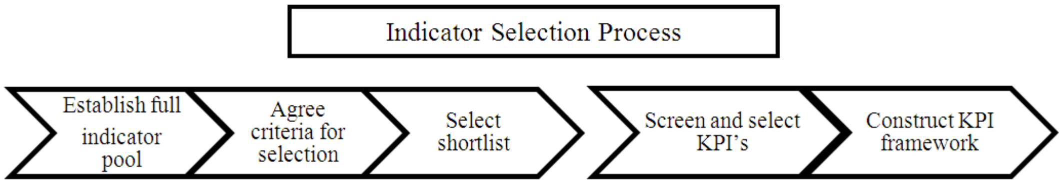

FIGURE 4: **THE PROCESS USED TO DETERMINE THE SET OF INDICATORS**

The next step as per the framework is to establish the criteria for shortlisting the indicator pool and identifying the sub criteria to be used in the AHP model for each of the three dimensions. Previous published literature indicates that environmental performance indicators for any sector can be divided into three categories namely, a) environmental impact parameters (No_x $emmissions$, water use, greenhouse gas emissions etc., b) regulatory compliance such as violation fees, non-compliance status etc., and c) organizational processes such as reporting standards etc (Delmas and Blass 2010). Similarly, the universally acclaimed Global Reporting Initiative framework states that the performance metrics for measuring firm social performance can be divided into four categories: Labor Practices and Decent Work, Human Rights, Society, and Product Responsibility (Aggarwal, P., 2013). In our study I have chosen the following categories for identifying criteria for environmental and social dimensions. The same are summarized:

- Environmental Dimension Metrics
    - Environmental Impact Parameters
- Social Dimension Metrics
    - Labor Practices & Decent Work
    - Society

The second filter criteria which has been used in this case study for shortlisting the KPI's is the presence of uniform quantitative unit of measurement for the indicator to be shortlisted. Thus from the exhaustive indicator pool shared in Tables 4.1, 4.2 and 4.3, all those metrics have been dropped for which IPIECA, API & IOGP have still not recommended a standard unit of measurement for publication of data.

In case of financial performance metrics, I have chosen to utilize the currently preferred metrics used by investment analysts, i.e. Revenues, Operating Cash Flow, Net Profit and Daily Oil Equivalent Production for measuring the relative firm performance. After shortlisting the criteria, we need to structure the shortlisted indicators in a hierarchical structure. The final Sustainable Operational Performance Index which has been used in this case study for evaluating firm operational performance for the oil & gas sector in 2014 is described in figure 5.

As discussed in Research Framework Section of Chapter III, post the creation of the KPI framework we need to follow one more step before developing the pairwise matrix for the operational performance indicators at the different levels of the index. The same is to normalize specific criteria/indicator in order to remove the geographic and firm size bias. For example, for specific sub criteria for the environmental and social dimensions such as Community Contribution, GHG emissions etc., we need to normalize the absolute values so as to remove the impact of the differential firm size. This is done by dividing the absolute value of the specific criteria with suitable variables such as"Net Profit / Revenue/ Daily Oil Equivalent Production ".

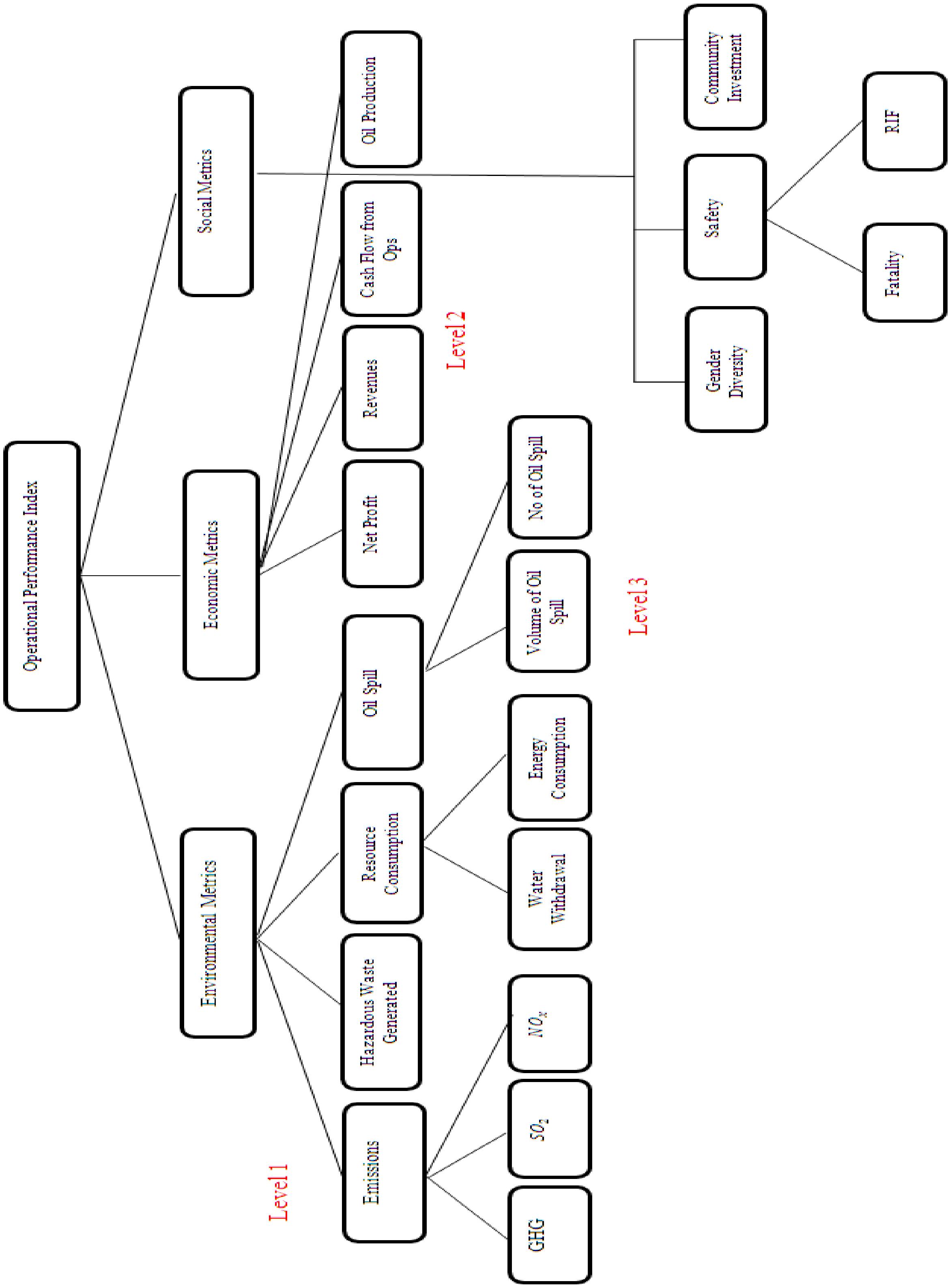

FIGURE 5: TBL PER*FO*RMANCE MEASUREMENT FRAMEWORK FOR OIL & GAS SECTOR

3.2 Allocation of Weights to Individual Performance Metrics by Multi-Level AHP

Section 3.2.2 elucidates that Analytic Hierarchy Process should be used for allocation of weights to the different operational performance metrics at every level of the Sustainable Performance Index. The generation of pairwise matrix for weight allocation at every level should ideally be based upon the judgements of the subject matter experts (SME) for the specific industry under consideration. A Likert point scale survey should be used to elicit the response of the SMEs with respect to the preference which should be given to every metric.

In this case study the allocation of weights to the operational performance metric have been based upon the subjective judgement/preference of the author. I have not adopted a survey based methodology primarily due to two reasons. Firstly, the primary objective of the research study is the proposal of a MCDM based process for evaluating relative performance of the firms on sustainable operational performance metrics and hence due to the scope limitation we have not ventured into eliciting SME opinions regarding the Sustainable Operational Performance Index proposed for oil & gas industry. Secondly, the multiple scenarios which get generated due to the different allocation of weights to the same performance metric result in a different ranking outputof the various firms which have been considered in this case study. The multiple ranking outputs generated are used as a supporting evidence to highlight the importance of having a SME based consensus approach regarding the weight allocation/preference for every operational performance metric.

We can easily identify from the diagram presented in Figure 5 that the proposed Oil & Gas Sustainable Operational Performance Index has three levels. In the AHP pairwise matrix generation, I have utilized my prior understanding of oil & gas industry to arrive at the below matrix for every level of the index.

Level 1 Index: Weight Allocation

Step 1: Generation of AHP Priority Ratio Scale by assigning relative preference for different metrics between the range $\frac{1}{9}$ and 9

TABLE 4.8: RESEARCHER'S PREFERENCE FOR TBL PILLARS FOR OIL & GAS INDUSTRY

TBL Pillars	TBL Pillars		
	Environmental	Economic	Social
Environmental	1	0.2	3
Economic	5	1	7
Social	0.33	0.14	1
Total	**6.3**	**1.3**	**11**

Step 2: Normalize the columns of the matrix and subsequently average the rows to identify the allocated weight for each metric. The weights of the three metrics are denoted as a, b, c respectively.

TABLE 4.9: CALCULATED WEIGHTS FOR TBL PILLARS FOR OIL & GAS INDUSTRY

TBL Pillars	TBL Pillars			Metric Weight
	Environmental	Economic	Social	
Environmental(a)	0.16	0.15	0.27	**0.19**
Economic(b)	0.79	0.74	0.64	**0.72**
Social(c)	0.05	0.11	0.09	**0.08**

Level 2 Index: Weight Allocation

Repeat steps 1 and 2 explained in weight allocation for Level 1 index in order to arrive at the weights to be allocated for each of the operational performance metrics at 2nd level of Sustainable Operational Performance Index. The weights of the metrics are denoted as a_i, b_i, c_i respectively.

TABLE 4.10A: RESEARCHER'S PREFERENCE FOR SAFETY OPERATIONAL PERFORMANCE METRICS

	Safety	Gender Diversity	Community Contribution
Safety	1	2	0.5
Gender Diversity	0.5	1	0.25
Community Contribution	2	4	1
Total	**3.5**	**7**	**1.75**

TABLE 4.10B: RESEARCHER'S PREFERENCE FOR ECONOMIC OPERATIONAL PERFORMANCE METRICS

Level 2 – Economic	Production	Cash Flow from operations	Net Profit	Revenues
Production	1	0.8	3	5
Cash Flow from operations	1.25	1	2	4
Net Profit	0.33	0.5	1	6
Revenues	0.2	0.25	0.17	1
Total	**2.8**	**2.6**	**6.2**	**16.0**

TABLE 4.10C: RESEARCHER'S PREFERENCE FOR ENVIRONMENTAL OPERATIONAL PERFORMANCE METRICS

Level 2 - Environment	Emissions	Hazardous Waste	Resource Consumption	Oil Spill
Emissions	1	3	5	0.5
Hazardous Waste	0.33	1	2	0.33
Resource Consumption	0.2	0.5	1	0.14
Oil Spill	2	3	7	1
Total	**3.5**	**7.5**	**15.0**	**2.0**

TABLE 4.11A: CALCULATED WEIGHTS FOR LEVEL 2 SOCIAL METRICS

	Safety	Gender Diversity	Community Contribution	Metric Weight
Safety (c_1)	0.29	0.29	0.29	**0.29**
Gender Diversity (c_2)	0.14	0.14	0.14	**0.14**
Community Contribution (c_3)	0.57	0.57	0.57	**0.57**

TABLE 4.11B: CALCULATED WEIGHTS FOR LEVEL 2ECONOMIC METRICS

	Production	Cash Flow from operations	Net Profit	Revenues	Metric Weight
Production (b_1)	0.36	0.31	0.49	0.31	**0.37**
Cash Flow from operations (b_2)	0.45	0.39	0.32	0.25	**0.35**
Net Profit (b_3)	0.12	0.20	0.16	0.38	**0.21**
Revenues (b_4)	0.07	0.10	0.03	0.06	**0.06**

TABLE 4.11C: CALCULATED WEIGHTS FOR LEVEL 2 ENVIRONMENTAL METRICS

	Emissions	Hazardous Waste	Resource Consumption	Oil Spill	Metric Weight
Emissions (a_1)	0.28	0.40	0.33	0.25	**0.32**
Hazardous Waste (a_2)	0.09	0.13	0.13	0.17	**0.13**
Resource Consumption (a_3)	0.06	0.07	0.07	0.07	**0.07**
Oil Spill (a_4)	0.57	0.40	0.47	0.51	**0.48**

Level 3 Index: Weight Allocation

Repeat steps 1 and 2 explained in weight allocation for Level 1 index in order to arrive at the weights to be allocated for environmental (Emissions, oil spill and resource) and social operational performance metric sub trees at 3rd level of Sustainable Operational Performance Index.

TABLE 4.12A: RESEARCHER'S PREFERENCE FOR SIGNIFICANCE OF FIRM PERFORMANCE ON DIFFERENT EMISSION OPERATIONAL PERFORMANCE METRICS

Level 3a: Environment – Emissions	GHG	SO2	Nox
GHG	1	0.25	0.33
SO2	4	1	2
Nox	3	0.5	1
Total	**8**	**1.75**	**3.33**

TABLE 4.12B: RESEARCHER'S PREFERENCE FOR SIGNIFICANCE OF FIRM PERFORMANCE ON OIL SPILL

Level 3b: Environment - Oil Spill	No	Volume
No	1	0.33
Volume	3	1.00
Total	**4**	**1.33**

TABLE 4.12C: RESEARCHER'S PREFERENCE FOR SIGNIFICANCE OF FIRM PERFORMANCE ON RESOURCE CONSUMPTION

Level 3c: Environment - Resource Consumption	Water Withdrawal	Energy Consumption
Water Withdrawal	1	0.50
Energy Consumption	2	1.00
Total	**3**	**1.50**

TABLE 4.12D: RESEARCHER'S PREFERENCE FOR SIGNIFICANCE OF FIRM PERFORMANCE ON SAFETY

Level 3d: Social – Safety	Fatality	RIF
Fatality	1	2
RIF	0.5	1
Total	**1.5**	**3**

TABLE 4.13A: CALCULATED WEIGHTS FOR LEVEL 3 ENVIRONMENT (EMISSION TREE) METRICS

Emission	GHG	SO2	Nox	Metric Weight
GHG (a_{11})	0.125	0.14	0.1	**0.12**
SO2 (a_{12})	0.5	0.57	0.6	**0.56**
Nox (a_{13})	0.375	0.29	0.3	**0.32**

TABLE 4.13B: CALCULATED WEIGHTS FOR LEVEL 3 ENVIRONMENT (OIL SPILL TREE) METRICS

Oil Spill	No	Volume	Metric Weight
No (a_{41})	0.25	0.25	**0.25**
Volume (a_{42})	0.75	0.75	**0.75**

TABLE 4.13C: CALCULATED WEIGHTS FOR LEVEL 3 ENVIRONMENT (RESOURCE TREE) METRICS

Resource Consumption	Water Withdrawal	Energy Consumption	Metric Weight
Water Withdrawal (a_{31})	0.33	0.33	**0.33**
Energy Consumption (a_{32})	0.67	0.67	**0.67**

TABLE 4.13D: CALCULATED WEIGHTS FOR LEVEL 3 SOCIAL (SAFETY) METRICS

Safety	Fatality	RIF	Metric Weight
Fatality (c_{11})	0.67	0.67	**0.67**
RIF (c_{12})	0.33	0.33	**0.33**

The last step in the calculation of the weights for the sustainable operational performance index metrics involves the aggregation of the weights. The weights of each of the operational performance sub criteria are shown below in Table 4.14. The table also categorizes each of the metrics as either a Positive Indicator/ Benefit Attribute or Negative Indicator/ Cost Attribute.

TABLE 4.14: AGGREGATED CALCULATED WEIGHTS FOR OPERATIONAL PERFORMANCE METRICS

Operational Metric	Weight	Type of Metric (Benefit/Cost)
GHG Emission / Revenue	0.008 = $(a * a_1 * a_{11})$	Cost
SO2 Emission / Revenue	0.034 = $(a * a_1 * a_{12})$	Cost
Nox Emission / Revenue	0.020 = $(a * a_1 * a_{13})$	Cost
Hazardous Waste / Revenue	0.026 = $(a * a_2)$	Cost
Water Withdrawal / Oil Production	0.004 = $(a * a_3 * a_{31})$	Cost
Energy Consumption / Oil Production	0.008 = $(a * a_3 * a_{32})$	Cost
Volume of Oil Spill	0.070 = $(a * a_4 * a_{42})$	Cost
No of Oil Spill	0.023 = $(a * a_4 * a_{41})$	Cost
Revenues	0.047 = $(b * b_4)$	Benefit
Net Profit	0.154 = $(b * b_3)$	Benefit
Cash flow from Operations	0.256 = $(b * b_2)$	Benefit
Oil Production	0.266 = $(b * b_1)$	Benefit
Gender Diversity	0.012= $(c * c_2)$	Benefit
Fatality	0.016 = $(c * c_1 * c_{11})$	Cost
RIF	0.008 = $(c * c_1 * c_{12})$	Cost
Community Investment / Net Profit	0.048 = $(c * c_3)$	Benefit

3.3 Ranking of Firms on Aggregated Scores using AHP and TOPSIS

In the earlier Sections, the three pillars of Triple Bottom Line on which a firm's operational performance needs to be measured in order to judge its robustness on sustainability parameters have been defined. Subsequently for the representative case study presented in this research study, the sustainability metrics from the annual firm sustainability reports were selected and classified t under the three TBL dimensions resulting in the proposed Sustainable Operational Performance Index for the oil & gas sector. Lastly in the previous Section 3.2 of Chapter IV, the weights which should be allocated to each of the individual metrics using multi-level AHP have been identified and discussed. Briefly this process has been explained in Chapter III under the research methodology Section. For the ease of the readers the multi – level AHP process for allocation of weights can be summarized as below:

Step 1: Confirm the dimensions in the first level

Step 2: Confirm the perspectives in each dimension in the second level

Step 3: Denote the weight of different sub-criteria as $a_{ij}, b_{ij} and\ c_{ij}$, respectively. a, b and c represent the weights allocated to the three TBL dimensions which have been analyzed in this research study proposal, i.e. environment, economy and society, respectively.

The next step as per the research framework is referred to as 'Ranking of Firms'. In this critical step users can utilize any of the multiple MCDM techniques which are available in order to rank the different alternatives on each of the identified operational performance metrics. As discussed in Chapter III, the use of either AHP or TOPSIS has been preferred for this purpose. In this Section the ranking of firms using both these MCDM methods has been calculated. Subsequently comparison of these ranks of the firms obtained using the AHP and TOPSIS method with the outputs derived using the standard SCORE method has also been discussed in this Section.

3.3.1 AHP Method Calculations

The ranking of firms using the AHP method is made completely objective by converting the underlying firm 2014 operational performance data into Saaty's AHP priority ratio scale. This has been achieved by using the principles proposed in Section 4, Chapter III of this study. As discussed earlier these proposed principles are generic and universally applicable for any AHP real world problem which has underlying secondary data for the different alternatives being considered in that problem. The method is demonstrated below for one of the sub-criteria for social metrics ‘Community Contribution/ Net Profit ‘.

TABLE 4.15: OPERATIONAL FIRM DATA FOR “COMMUNITY CONTRIBUTION/NET PROFIT” FOR THE YEAR 2014

Firm Name	Community Cont/Net Profit
BP	21.2
Chevron	12.5
Shell	10.9
Petrobras	51.6
ONGC	20.6
Repsol	16.5
Petronas	10.4
Total	47.7
ExxonMobil	8.6
Rosneft	6.4
Husky	3.5

Step 1: Use equation 9 and 10 stated in Section 4, Chapter III to map the relative difference between two alternatives into an equivalent value of parameter K. For the above data for Community contribution the mapping results are shared in Table 4.16

TABLE 4.16: MAPPING OF RELATIVE DIFFERENCE OF ALTERNATIVE DATA INTO SAATY’S PRIORITY SCALE

K	9	8	7	6	5	4	3	2	1
Max Difference	48.11	42.10	36.09	30.07	24.06	18.04	12.03	6.01	0.00

Step 2: Develop the equivalent AHP priority ratio scale using equations 9 and 10.

TABLE 4.17: PAIRWISE MATRIX FOR "COMMUNITY CONTRIBUTION/NET PROFIT" USING AHP

Name of the Firms	BP	Chevron	Shell	Petrobras	ONGC	Repsol	Petronas	Total	ExxonMobil	Rosneft	Husky
BP	1.0	2.5	2.7	0.2	1.1	1.8	2.8	0.2	3.1	3.5	4.0
Chevron	0.4	1.0	1.3	0.1	0.4	0.6	1.3	0.1	1.6	2.0	2.5
Shell	0.4	0.8	1.0	0.1	0.4	0.5	1.1	0.1	1.4	1.7	2.2
Petrobras	6.0	7.5	7.8	1.0	6.1	6.8	7.8	1.7	8.2	8.5	9.0
ONGC	0.9	2.4	2.6	0.2	1.0	1.7	2.7	0.2	3.0	3.4	3.9
Repsol	0.6	1.7	1.9	0.1	0.6	1.0	2.0	0.2	2.3	2.7	3.2
Petronas	0.4	0.7	0.9	0.1	0.4	0.5	1.0	0.1	1.3	1.7	2.2
Total	5.4	6.8	7.1	0.6	5.5	6.2	7.2	1.0	7.5	7.9	8.3
ExxonMobil	0.3	0.6	0.7	0.1	0.3	0.4	0.8	0.1	1.0	1.4	1.8
Rosneft	0.3	0.5	0.6	0.1	0.3	0.4	0.6	0.1	0.7	1.0	1.5
Husky	0.3	0.4	0.4	0.1	0.3	0.3	0.5	0.1	0.5	0.7	1.0
Total	**15.9**	**24.9**	**27.1**	**2.8**	**16.4**	**20.2**	**27.8**	**4.0**	**30.7**	**34.3**	**39.5**

Step 3: Normalize each of the rows and calculate the equivalent rank scores for each firm for the specific criteria under consideration.

TABLE 4.18: FIRM RANK SCORES FOR "COMMUNITY CONTRIBUTION/NET PROFIT" USING AHP

Name of the Firms	BP	Chevron	Shell	Petrobras	ONGC	Repsol	Petronas	Total	Exxon Mobil	Rosneft	Husky	Firm Rank Score
BP	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	**0.08**
Chevron	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	**0.04**
Shell	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	**0.04**
Petrobras	0.4	0.3	0.3	0.4	0.4	0.3	0.3	0.4	0.3	0.2	0.2	**0.32**
ONGC	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	**0.08**
Repsol	0.0	0.1	0.1	0.1	0.0	0.0	0.1	0.0	0.1	0.1	0.1	**0.06**
Petronas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	**0.04**
Total	0.3	0.3	0.3	0.2	0.3	0.3	0.3	0.3	0.2	0.2	0.2	**0.27**
Exxon Mobil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.03**
Rosneft	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.03**
Husky	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.02**

Step 4: Repeat Steps 1 to 3 explained above for each of the remaining 15 operational performance metrics. The resultant rank score for each of the firms is shown below and are represented by K_{ij}, where "i" refers to the i^{th}.firm and "j" refers to the j^{th} criteria in the performance index.

TABLE 4.19: RANK SCORES FOR DIFFERENT ALTERNATIVES FOR EACH CRITERIA

Name of the Firms	GHG	SO2	Nox	Hazardous Waste	Water Withdrawal	Energy Consumption	Volume of Oil Spill	No of Oil Spill	Revenues	Net Profit	Cash Flow from Operations	Oil Production	Gender Diversity	Fatality	RIF	Community Investment
BP	0.2	0.2	0.1	0.2	0.0	0.2	0.1	0.1	0.2	0.0	0.1	0.1	0.0	0.2	0.1	0.1
Chevron	0.1	0.0	0.1	0.0	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.0
Shell	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.3	0.1	0.2	0.1	0.1	0.1	0.1	0.0
Petrobras	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.1	0.0	0.1	0.0	0.3
ONGC	0.0	0.1	0.1	0.1	0.2	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1
Repsol	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.2	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.1
Petronas	0.1	0.0	0.0	0.2	0.3	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0
Total	0.1	0.1	0.1	0.1	0.1	0.2	0.0	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.3
ExxonMobil	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.2	0.3	0.2	0.2	0.1	0.2	0.1	0.0
Rosneft	0.1	0.0	0.1	0.0	0.0	0.1	0.1	0.1	0.0	0.2	0.1	0.3	0.2	0.0	0.2	0.0
Husky	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0

Step 5: Evaluate the comprehensive performance of each of the 11 firms. The aggregated firm operational performance obtained from either AHP or TOPSIS methods can be derived using the following formula:

➢ Comprehensive Firm Score for $i^{th}\ firm$ is:

$$S_i = \sum_{j=1;x=1;y=1}^{j=8;x=4;y=3} K_{ij}aa_x a_{xy} + \sum_{j=9;x=1}^{j=12;x=4} K_{ij}b_x b + \sum_{j=13;x=1;y=1}^{j=16;x=3;y=2} K_{ij}c_{xy}cc_x$$

……….. (12)

Application of Equation 12 results in the final Firm scores for Sustainable Operation Performance using the AHP method. The results are shown in Table 4.20.

TABLE 4.20: AGGREGATED FIRM SCORES USING AHP

Firm Name	BP	Chevron	Shell	Petrobras	ONGC	Repsol	Petronas	Total	ExxonMobil	Rosneft	Husky
AHP Score	0.11	0.09	0.14	0.07	0.05	0.04	0.07	0.07	0.20	0.13	0.04

The reliability of the results obtained by the application of AHP method needs to be validated by calculating the consistency ratio for each of the pairwise matrices generated in the calculation. The biggest advantage of the principles proposed in this study in Section 3.3 for mapping of alternative data for specific criteria into the equivalent AHP pairwise matrix is that it ensures the objectivity of the process. The same is reflected in the really low values of consistency ratio which are obtained as CR << 0.1. The process for the calculation of consistency ratio as explained in Chapter III is demonstrated for the pairwise matrix generated for the firms for the criteria "Community Contribution/ Net Profit ".

$$AX = \lambda_{max} X$$

$$X = \begin{bmatrix} a \\ b \\ c \end{bmatrix}$$

$$AX = \begin{bmatrix} AX_1 \\ AX_2 \\ AX_3 \end{bmatrix}$$

$$\lambda = \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \end{bmatrix} = \begin{bmatrix} AX_1 \div a \\ AX_2 \div b \\ AX_3 \div c \end{bmatrix}$$

$$\lambda_{max} = \frac{\lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 + \ldots . \lambda_n}{n}$$

$CI = \frac{\lambda_{max} - n}{n-1}$, where $n = 11$, thereby, $CI = 0.03$

$$\boldsymbol{CR = \frac{CI}{RI} = \frac{0.028}{1.51} = 0.02}$$

Thus it can be seen that $\boldsymbol{CR} < 0.1$ and hence the AHP pairwise matrix is quite consistent.

3.3.2 TOPSIS Method Calculations

As discussed in Section 4.2, Chapter II of this study TOPSIS method will look for the preferred firm which has the shortest distance from the PIS and the longest distance from the NIS. The implementation of the TOPSIS process is demonstrated below for the 11 oil and gas sector firms which have been considered in this case study. We need to remember that as explained in the research framework, the weights for each of the metrics have been derived from the multi-level AHP process itself and hence the first two steps of the research framework proposed for evaluating firm sustainable operational performance remain the same irrespective of the MCDM technique which is used for ranking the firms.

Step 1: Normalize the firm ratings for each of the operational performance metrics.

TABLE 4.21A: NORMALIZED FIRM RATINGS FOR SOCIAL OPERATIONAL PERFORMANCE METRICS

Firm Name	Social			
	Fatalities	RIF	Women %	Community Cont/Net Profit
BP	0.1	0.2	0.3	0.3
Chevron	0.1	0.1	0.3	0.2
Shell	0.1	0.1	0.3	0.1
Petrobras	0.2	0.7	0.2	0.6
ONGC	0.1	0.1	0.1	0.3
Repsol	0.2	0.3	0.4	0.2
Petronas	0.2	0.1	0.3	0.1
Total	0.2	0.2	0.4	0.6
ExxonMobil	0.1	0.2	0.3	0.1
Rosneft	0.8	0.0	0.4	0.1
Husky	0.2	0.5	0.3	0.0
Weights	0.016	0.008	0.012	0.048

TABLE 4.21B: NORMALIZED FIRM RATINGS FOR ENVIRONMENTAL OPERATIONAL PERFORMANCE METRICS

Firm Name	Environmental							
	No of Oil Spills	Volume of Oil Spills (mnltrs)	GHG Emission/ Revenue	SO2 Emission/ Revenue	NOx Emission/ Revenue	Hazardous Waste Generated/ Revenue	Freshwater Withdrawal/ Production	Energy Consumption/ Revenues
BP	0.1	0.1	0.1	0.1	0.1	0.1	0.4	0.1
Chevron	0.1	0.0	0.1	0.3	0.2	0.5	0.2	0.2
Shell	0.3	0.1	0.1	0.1	0.1	0.1	0.3	0.2
Petrobras	0.1	0.0	0.3	0.6	0.8	0.2	0.4	0.3
ONGC	0.0	0.0	0.8	0.3	0.2	0.1	0.2	0.8
Repsol	0.0	0.1	0.1	0.3	0.2	0.1	0.4	0.1
Petronas	0.0	0.1	0.2	0.4	0.4	0.0	0.1	0.2
Total	0.2	0.9	0.1	0.2	0.1	0.1	0.2	0.1
ExxonMobil	0.6	0.2	0.1	0.1	0.1	0.1	0.3	0.2
Rosneft	0.2	0.2	0.2	0.3	0.2	0.8	0.3	0.2
Husky	0.6	0.0	0.3	0.2	0.1	0.2	0.3	0.2
Weight	0.02	0.07	0.01	0.03	0.02	0.03	0.00	0.01

TABLE 4.21C: NORMALIZED FIRM RATINGS FOR ECONOMIC OPERATIONAL PERFORMANCE METRICS

Firm Name	Economic			
	Operating Cash Flow ($ billion)	Total Hydrocarbons Produced (thousand barrels of oil equivalent (mboe) per day)	Net Profit ($ billion)	Revenues($ billion)
BP	0.3	0.4	0.1	0.5
Chevron	0.3	0.3	0.4	0.3
Shell	0.5	0.3	0.3	0.5
Petrobras	0.3	0.3	-0.2	0.2
ONGC	0.0	0.1	0.1	0.0
Repsol	0.0	0.1	0.0	0.1
Petronas	0.3	0.3	0.3	0.1
Total	0.3	0.2	0.3	0.3
ExxonMobil	0.5	0.5	0.6	0.5
Rosneft	0.3	0.5	0.4	0.1
Husky	0.0	0.0	0.0	0.0
Weights	0.256	0.266	0.154	0.047

Step 2: Calculate $y_{ij} = w_i r_{ij}$…… as defined in equation 4 in Chapter II of theresearch study. Also calculate PIS and NIS.

TABLE 4.22A: WEIGHTED FIRM RATINGS FOR SOCIAL OPERATIONAL PERFORMANCE METRICS

Firm Name	Social			
	Fatalities	RIF	Women %	Community Cont/Net Profit
BP	0.001	0.002	0.003	0.012
Chevron	0.001	0.001	0.003	0.007
Shell	0.002	0.001	0.004	0.006
Petrobras	0.004	0.005	0.002	0.030
ONGC	0.002	0.001	0.001	0.012
Repsol	0.003	0.003	0.004	0.010
Petronas	0.004	0.001	0.004	0.006
Total	0.003	0.001	0.004	0.028
ExxonMobil	0.001	0.001	0.004	0.005
Rosneft	0.013	0.000	0.005	0.004
Husky	0.003	0.004	0.003	0.002
Positive Ideal Solution	0.013	0.005	0.005	0.030
Negative Ideal Solution	0.001	0.000	0.001	0.002

TABLE 4.22B: WEIGHTED FIRM RATINGS FOR ECONOMIC OPERATIONAL PERFORMANCE METRICS

Firm Name	Economic			
	Operating Cash Flow ($ billion)	Total hydrocarbons produced (thousand barrels of oil equivalent (mboe) per day)	Net Profit ($ billion)	Revenues($ billion)
BP	0.087	0.095	0.012	0.022
Chevron	0.084	0.077	0.059	0.012
Shell	0.120	0.093	0.045	0.026
Petrobras	0.071	0.080	-0.025	0.008
ONGC	0.012	0.035	0.009	0.001
Repsol	0.010	0.017	0.006	0.003
Petronas	0.079	0.067	0.041	0.006
Total	0.068	0.063	0.039	0.014
ExxonMobil	0.120	0.120	0.099	0.024
Rosneft	0.076	0.128	0.067	0.006
Husky	0.013	0.010	0.004	0.001
Positive Ideal Solution	0.120	0.128	0.099	0.026
Negative Ideal Solution	0.010	0.010	-0.025	0.001

TABLE 4.22C: WEIGHTED FIRM RATINGS FOR ENVIRONMENTAL OPERATIONAL PERFORMANCE METRICS

Firm Name	Environmental							
	No of Oil Spills	Volume of Oil Spills (mnltrs)	GHG Emission/ Revenue	SO2 Emission/ Revenue	NOx Emission/ Revenue	Hazardous Waste Generated/ Revenue	Freshwater Withdrawal/ Production	Energy Consumption/ Revenues
BP	0.003	0.005	0.000	0.002	0.002	0.001	0.002	0.001
Chevron	0.003	0.002	0.001	0.011	0.005	0.012	0.001	0.001
Shell	0.007	0.010	0.001	0.005	0.002	0.004	0.001	0.002
Petrobras	0.001	0.001	0.002	0.021	0.015	0.005	0.001	0.003
ONGC	0.000	0.000	0.006	0.009	0.005	0.004	0.001	0.007
Repsol	0.001	0.004	0.001	0.010	0.004	0.003	0.002	0.001
Petronas	0.001	0.007	0.001	0.013	0.007	0.001	0.000	0.002
Total	0.006	0.066	0.001	0.005	0.003	0.003	0.001	0.001
ExxonMobil	0.015	0.016	0.001	0.005	0.002	0.002	0.001	0.001
Rosneft	0.005	0.012	0.002	0.011	0.003	0.020	0.001	0.001
Husky	0.014	0.000	0.002	0.007	0.003	0.005	0.001	0.002
Positive Ideal Solution	0.015	0.066	0.006	0.021	0.015	0.020	0.002	0.007
Negative Ideal Solution	0.000	0.000	0.000	0.002	0.002	0.001	0.000	0.001

Step 3: Calculate the Euclidean distances of each alternative from PIS and NIS.

TABLE 4.23: EUCLIDEAN DISTANCES FOR EACH FIRM

Firm Name	Positive Ideal Solution		Negative Ideal Solution	
BP	0.02	0.12	0.01	0.12
Chevron	0.01	0.11	0.02	0.13
Shell	0.01	0.09	0.02	0.16
Petrobras	0.03	0.16	0.01	0.10
ONGC	0.03	0.19	0.00	0.04
Repsol	0.04	0.20	0.00	0.03
Petronas	0.01	0.12	0.01	0.11
Total	0.01	0.11	0.02	0.12
ExxonMobil	0.00	0.06	0.04	0.20
Rosneft	0.01	0.09	0.03	0.17
Husky	0.04	0.20	0.00	0.03

Step 4: Calculate overall performance of each alternative using $RC_j = \frac{D_j^-}{D_j^- + D_j^+}$, i.e. equation 7 stated earlier in Chapter II of the study. The firms are then ranked in the descending order of RC_j . We could also calculate $RC'_j = \frac{D_j^+}{D_j^- + D_j^+}$ and then rank the firms in the ascending order of RC'_j. Both the methods should give the same results.

TABLE 4.24: OVERALL FIRM PERFORMANCE ON SUSTAINABLE OPERATIONAL PERFORMANCE INDEX USING TOPSIS

Firm Name	BP	Chevron	Shell	Petrobras	ONGC	Repsol	Petronas	Total	ExxonMobil	Rosneft	Husky
Ranking Score	0.50	0.65	0.71	0.45	0.39	0.29	0.56	0.47	0.86	0.72	0.29

The results derived by either AHP (Table 4.20) or TOPSIS (Table 4.24) can be used by investors for positive screening i.e. the ranking of the firms derived by this method can reflect the preference order for the investors.

4. Findings of Case Study and Discussion of Results

It needs to be emphasized that the objective of the case study demonstrated in this research study was to create awareness about the utility of multi –level AHP for the SRI problem. The' final operational performance scores' derived for the oil & gas sector firms for 2014 and shared in Table 4.20 and Table 4.24 are just an indication value.

The ranking of the firms has been impacted by the researcher's perception in terms of allocation of weights for the creation of the pairwise matrix for the financial, social and environmental parameters. The financial investing community and the oil & gas sector experts are more qualified than the researcher to more accurately reflect the real life scenarios while creating the pairwise matrix for allocation of weights to the three TBL pillars. The rank scores which would be obtained by this research framework on the basis of the 'weights for the different operational performance metrics' which are generated using pairwise matrix basis their preferences would be a more accurate reflection of the firm operational performance for 2014.

4.1 Comparative Analysis of Results Derived from AHP, TOPSIS and SCORE

The final results obtained for the demonstrated case study derived using the AHP and TOPSIS methods are compared with the results derived from a standard SCORE method which is based on normalization of firm ratings. The comparison results are summarized below in Table 4.25.

TABLE 4.25: FIRM SCORES ON SUSTAINABLE OPERATIONAL PERFORMANCE INDEX BY DIFFERENT MCDM METHODS

Name of the Firms	Scoring 1	TOPSIS	AHP
BP	0.090	0.584	0.105
Chevron	0.104	0.647	0.089
Shell	0.121	0.706	0.140
Petrobras	0.079	0.451	0.073
ONGC	0.038	0.328	0.046
Repsol	0.031	0.290	0.040
Petronas	0.089	0.563	0.072
Total	0.126	0.472	0.075

ExxonMobil	0.159	0.857	0.196
Rosneft	0.135	0.715	0.130
Husky	0.029	0.287	0.035

The firms have been ranked in descending order of the scores and the comparative data has been presented in Table 4.26.

TABLE 4.26: FIRM RANKING ON SUSTAINABLE OPERATIONAL PERFORMANCE INDEX

Rank	Scoring 1	TOPSIS	AHP
I	ExxonMobil	ExxonMobil	ExxonMobil
II	Rosneft	Rosneft	Shell
III	Total	Shell	Rosneft
IV	Shell	Chevron	BP
V	Chevron	BP	Chevron
VI	BP	Petronas	Total
VII	Petronas	Total	Petrobras
VIII	Petrobras	Petrobras	Petronas
IX	ONGC	ONGC	ONGC
X	Repsol	Repsol	Repsol
XI	Husky	Husky	Husky

The three different MCDM methods present slightly different order of firm rankings for 2014 sustainable operational performance. This is an interesting trend which can be taken up as a future research direction. The different firm ranks derived by AHP, TOPSIS and SCORE methods is in spite of the weights for the different sustainable operational performance metrics being considered equal in the case study. Previous empirical studies which made a comparative review of results derived for research problem by application of different MADM methods, indicated that research problems which have larger number of alternatives usually result in different results by application of different MADM methods(Zanakis, Solomon et al. 1998). This is a limitation associated with all multi attribute decision making problems and the best research framework solutions try to minimize this difference. In the research framework proposed in our study too, we have tried to achieve this objective by making the following two recommendations:

i. As an evolutionary process it is envisaged that as an ideal final step, the weights allocated to the different sustainable operational performance metrics for evaluating firms in any specific sector would be based on the consensual opinion of the sector specific experts.

ii. The research framework proposed in Chapter III of this study for evaluating firm performance on sustainability metrics recommends a multi-level AHP based process for calculating the weights to be allocated to the different metrics. Thus this reduces the wide difference in output results which might be attained by subsequent application of different MCDM techniques for ranking the firm ratings on these metrics and aggregating the firm scores.

The study recommends AHP and TOPSIS as the two preferred MCDM methods for ranking the firm ratings on the individual performance metrics and subsequently aggregating the scores. Analysts can choose either one of these methods depending upon their individual familiarity with the two methods.

5. Operational Performance Trends for Oil & Gas Sector Firms

As discussed in the "Introduction" Section of Chapter III of this research study the operational performance trends for oil and gas sector firms have been tested for the following hypotheses:

H0: National Oil Companies perform equally well as International Oil Companies and Private Oil Companies on social performance indicators

H1: National Oil Companies do not perform similarly as International Oil Companies and Private Oil Companies on social performance indicators

H0': International Oil Companies perform equally well as National Oil Companies on environmental performance indicators

H1': International Oil Companies do not perform similar to National Oil Companies on environmental performance indicators

5.1 Data Collection

In addition to the 11 firms which have been considered in the case study demonstrated in Chapter IV of this research study, 4 more oil & gas sector firms namely ENI, Conoco Phillips, Suncor and Pemex. The 15 firms have been classified on the basis of their ownership structure. The government controlled oil & gas firms i.e firms where more than 50% of the shares are owned by government institutions have been classified as "National Oil Companies" (NOC). Firms in which the government stake is less than 50% are classified as privately owned enterprises. Furthermore, the privately owned enterprises are further categorized on the basis of their geographical spread of operations. Private oil & gas firms who have operations primarily limited to specific geographical regions are classified as "privately owned oil companies" (POC) while the private oil & gas firms having operations spread across the globe i.e. more than two continents are referred to as "International Oil Companies" (IOC). The 2014 operational performance data for all the 15 firms forms the dataset which is considered for running the statistical tests. Table 4.27 presents the distribution of the dataset considered for running the statistical tests.

TABLE 4.27: DISTRIBUTION OF FIRMS AS PER OWNERSHIP & SPREAD OF OPERATIONS

Firm Name	Category of Firm
BP	IOC
Chevron	IOC
Shell	IOC
Petrobras	NOC
ONGC	NOC
Repsol	POC
Petronas	NOC
Total	IOC
Exxon Mobil	IOC
Rosneft	NOC
Husky	POC
ENI	POC
Conoco Phillips	IOC
Suncor	POC
Pemex	NOC

The terms "Social Performance" and Environmental Performance" are defined by utilizing the weights for the different dimension sub metrics which have been derived earlier in the research study using AHP. The mathematical representation of the two variables is shown below:

Social Performance = 0.14 * Female Employee % + 0.57* Community Contr/Net Profit + 0.19* No. of Fatality + 0.1 * Recordable Injury Frequency (RIF)……..(13)

Environmental Performance = 0.13*Hazardous Waste + 0.039*GHG Emission+0.177*SO2 Emission + 0.101*NOx Emission + 0.12*No. of Oil Spill + 0.36* Volume of Oil Spill +0.02* Fresh Water Withdrawn + 0.04* Energy Consumed …… (14)

5.2 Testing of Hypotheses

5.2.1 Social Operational Performance Test Results and Analysis

The Levene statistic value was less than 0.05, highlighting that One Way Analysis of Variance (ANOVA) statistical test could be performed on the data for the proposed Hypothesis H1. The Levene statistic results are shown below.

TABLE 4.28: SOCIAL OPERATIONAL PERFORMANCE LEVENE STATISTIC RESULTS

Social_Performance			
Levene Statistic	**df1**	**df2**	**Sig.**
49.178	2	11	.000

The p value for the ANOVA for H1 is 0.145. As the p value is greater than the required limit of 0.05 (95% confidence interval) thus the **hypothesis H1 is rejected**. The detailed ANOVA results are presented in Table 4.29.

TABLE 4.29: SOCIAL OPERATIONAL PERFORMANCE ANOVA RESULTS

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	6767.055	2	3383.528	2.309	.145
Within Groups	16119.585	11	1465.417		
Total	22886.641	13			

5.2.2 Environmental Operational Performance Test Results and Analysis

The Levene statistic/ Test of Homogeneity could not be performed as only one of the three categories of firms had a computed variance. The same is probably due to lack of data for some of the firms specifically for the variable "Freshwater Withdrawn". The p value for the ANOVA for H1 is 0.324. As the p value is greater than the required limit of 0.05 (95% confidence interval) thus the **hypothesis H2 is also rejected**. The detailed ANOVA results are presented in Table 4.30.

TABLE 4.30: ENVIRONMENTAL OPERATIONAL PERFORMANCE ANOVA RESULTS

ANOVA					
Environmental_Performance					
	Sum of Squares	**Df**	**Mean Square**	**F**	**Sig.**
Between Groups	10359.699	2	5179.850	1.682	.324
Within Groups	9241.282	3	3080.427		
Total	19600.981	5			

The ANOVA results on the 2014 operational performance data of the firms under consideration do not highlight a better social operational performance for the National Oil Companies in comparison to their International Oil Company peers. Similarly, the data does not reflect a better performance by the International Oil Companies than their government owned peers on environmental operational performance metrics. Thus both the null hypothesis H0 and H0’ with regard to trends in social and operational performance of oil & gas sector firms cannot be rejected.

CHAPTER V

CONCLUSION

1. Conclusion

In this research study, the effectiveness of MCDM methods for evaluating the relative operational performance of firms on sustainable metrics have been demonstrated. A case study of 11 firms in the oil & gas sector was utilized for demonstrating the implementation of the research framework proposed in this study. The data reported by each of the firms in their respective 2014 sustainability reports was the source of secondary data used for comparison of the firms on sustainable operational performance metrics using MCDM methods such as AHP and TOPSIS. The methods will be similar to the case study demonstrated in this research study. The results derived by the application of these methods could be used by the SRI community either for positive screening. SRI involves tradeoffs depending upon the individual investor preferences for the three pillars of TBL i.e. environmental, social and financial performance. As a result, these tradeoffs/investor preferences substantially impact the pairwise matrix for the different TBL criteria and this results in different firm operational performance scores on TBL parameters.

Given the need for establishing a consensus on the specific sub - criteria which should be considered for evaluating firm performance in each sector (SIC) and the specific weight which should be allocated to each sub-criteria it is recommended that in the formative years these techniques of multi-level MCDM be used for negative screening by SRI investors. With the progressive diffusion of this quantitative method, it can be expected that TBL performance indicators would undergo the same transition as has been the case of financial indicators ultimately leading to a consensus among the relevant TBL criteria to be adopted for each sector. Once this stage is attained then the proposed MCDM framework can be used for positive screening by SRI funds.

The last major contribution of this research study is in the domain of AHP. The generic mathematical principles proposed in this research study for mapping of alternative rating data for an individual attribute into Saaty's AHP pairwise matrix. These mathematical principles can be used for application of AHP method for finding the most preferred choice for a multi attribute, multi alternative decision making problem. The application of these principles reduces the subjective judgement involved in generation of pairwise matrix for comparative alternative rating for a specific attribute.

2. Limitations of Research Study

The research methodology proposed for the research study has a few limitations. The first limitation is the generation of pairwise matrix for different criteria weights at each level. In the case study demonstrated in this research study, the researcher has utilized the existing literature and his own understanding of the oil & gas industry to rank the different criteria in terms of their importance to each other. This methodology can be improved by obtaining survey responses from a larger number of industry experts for their respective preferences on relative importance of performance metrics vis a vis to other metrics. Therein lies the justification for the approach as in all fairness, the research question of relative performance metric weight is an industry specific question and can be best dealt by experts of each specific industry. As highlighted earlier the objective of the case study in the research study was to demonstrate the application of quantitative methods for aiding different stakeholders for evaluating firms on sustainable operational performance metrics.

The second limitation of the research study is specific to AHP, which is one of the quantitative MADM methods that has been utilized for implementing the research framework proposed in the research study. As in any decision making problem which adopts AHP technique for its solution, this problem solution also suffers from the rank reversal limitation. The addition or deletion of any firm to the set of firms whose relative firm performance is being evaluated requires that the entire calculations need to be executed again. This is one of the limitations of AHP method due to which TOPSIS technique can be preferred for evaluating this decision making problem of identifying the rank of firms on the basis of their sustainable operational performance.

The last major limitation of the research work lies in the use of Levene statistic for identifying if ANOVA statistical test could be performed on the 2014 operational performance data of oil and gas sector firms for identifying if any trends could be extrapolated for the operational performance of the firms. Instead the use of Brown Forsythe test would have been more appropriate.

3. Future Research Areas

The framework proposed in this research study for evaluating the relative operational performance of firms on sustainability metrics leverages the conventional MADM methods of AHP and TOPSIS. Future research studies may be conducted in order to firstly test the resilience of the proposed framework for firms in other sectors such as automobiles etc. Moreover, we can also try to utilize the alternate TOPSIS methods where instead of utilizing Euclidean distances we can calculate the absolute distance of each alternative from the PIS and NIS.

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