Country and Company Sustainable Supply Chain Management by Using Multiple-Criteria Decision Making Approaches

by

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ABSTRACT

Economic, social, and environmental uncertainty plays a crucial role in the implementation of supply chain management. Herein, the present study establishes sustainable supply chain management indices (SSCMI) including Logistical Performance Index (LPI) and Worldwide Governance Index (WGI) along with the sustainability indices adopted from Bilbao-Terol (2014): Adjusted Net Savings (ANS), Ecological Footprints (EF), Environmental Performance Index (EPI), and Human Development Index (HDI). All data used in the present work are publically available from reliable sources such as the World Bank, the Global Footprint Network, and the Yale University. Three sets of data are compared; Triple-Bottom Line (TBL), TBL+LPI, and SSCMI. TBL includes four indices adopted from Bilbao-Terol (2014), TBL+LPI adds LPI to TBL, and SSCMI adds WGI to TBL+LPI. Equal weights, Analytic Hierarchy Process (AHP), and the Technique for Order Preferences by Similarity to Ideal Solution (TOPSIS) are applied to three different datasets and compare sustainability rankings. The results are mapped into a world map for geographical visualization. Sustainability reports of Heineken Company from 22 countries are collected and empirical data are extracted and examined. The comparison of country and company sustainable supply chain management is not analyzed due to a lack of company information. However, in the presence of complete data from company sustainability reports, the analysis used in this thesis is practical and useful to observe relationship between country and company sustainable supply chain management.

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TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

Figures

Tables

LIST OF ABBREVIATIONS

AHP: Analytic Hierarchy Process

ANS: Adjusted Net Savings

CC: Control of Corruption

CEI: Cumulative Eco-intensity

CEI: Cumulative Eco-intensity

CERES: Coalition for Environmentally Responsible Economies

CI: Consistency Index

CSR: Corporate Social Responsibility

DEMATEL: Decision-making Trial and Evaluation Laboratory

DM: Decision Maker

EF: Ecological Footprint

EMAS: Eco-Management and Audit Scheme

EMS: Environmental Management Systems

EPI: Environmental Performance Index

ESI: Environmental Sustainability Index

FTE: Full-time Equvalent

GDP: Gross Domestic Product

GE: Government Effectiveness

GHG: Greenhouse Gas

GNI: Gross National Income

GNP: Gross National Product

GRI: Global Reporting Initiative

GSCM: Green Supply Chain Management

GSCP: Green Supply Chain Practices

HDI: Human Development Index

ISO: International Organization for Standardization

LCA: Life-cycle Assessment

LM: Lean Management

LPI: Logistical Performance Index

MCDM: Multiple-Criteria Decision Making

NFAs: National Footprint Accounts

NGO: Non-governmental Organization

NRA: Normalization of Row Average

PPP: Purchasing Power Parity

PV: Political Stability and Absence of Violence/ Terrorism

RL: Rule of Law

RQ: Regulatory Quality

RSCM: Reverse Supply Chain Management

SC: Supply Chain

SCM: Supply Chain Management

SN: Supply Network

SPR: Sustainability Performance Ranking

SSCM: Sustainable Supply Chain Management

SSCMI: Sustainable Supply Chain Management Indices

SWOT: Strengths, Weaknesses, Opportunities and Threats

TBL: Triple-Bottom Line

TOPSIS: Technique for Order Preferences by Similarity to Ideal Solution

UCM: Unobserved Components Model

UNEP: United Nations Environment Programme

VA: Voice and Accountability

VAT: Value Added Tax

WGI: Worldwide Governance Index

CHAPTER I. INTRODUCTION

1 Introduction

"Sustainable development, which implies meeting the needs of the present without compromising the ability of future generations to meet their own needs, should become a central guiding principle of the United Nations, Governments, and private institutions, organizations and enterprises (WCED, 1987)"

Current generations are living in the resource-intensive world pursuing economic wealth, and encountering multiple problems such as inadequate social and poverty protection, resource depletion and environment damages, and economical unstableness. What is the true meaning of being wealthy? Wealth does not include only reproducible capital goods, human capital, and natural capital, but also includes population, public knowledge, and the institutions (Arrow, Dasgupta, Goulder, Mumford, and Oleson (2010)). Seeking a true meaning of wealth across the globe, sustainability – in other words, sustainable development – is increasingly discussed in a multi-dimensional and dynamic complex world, not only by individual corporations and businesses, but also by policy makers, the popular press, and journals in various fields of study (Linton, Klassen, & Jayaraman, 2007). Numerous definitions, indicators, and methodologies have been developed to identify sustainability, but many appear to be too ambiguous. Moerover, the existing evaluations and assessments are not very effective (Pope, Annandale, & Morrison-Saunders, 2004; Phillis and Andriantiatsaholinianina, 2001). One of the most commonly known terms of sustainability is called a triple bottom-line (TBL) with three aspects; economic, social, and environmental partnerships (Elkington, 1998). Kemp, Parto, and Gibson (2005), however, argue that this main three-dimensional model fails to address the interconnections among the concepts as sustainability is about both intermediate and long-term integration. As in the WCED (1987) statement, sustainable development should occur at all levels from local businesses to national and international governments and therefore governance should play a role to connect such activities. Bozarth *et al.* (2009) argue that as supply chain partners are becoming more geographically dispersed, their SCM and decision maker (DM) perspectives need to broaden the scope of business activities. Therefore the argument of Kemp, Parto, and Gibson (2005) has value in this study. Having governance as one of the aspect of sustainability would be beneficial due to "the need to establish governance structures and practises that can foster, guide, and coordinate positive work by a host of actors on a vast complex of issues, through webs of interconnection and across the multi-levels and scales, with sensitivity to their context". Kemp, Parto, and Gibson also argues, however, that governance of some of national government needs more improvement as it seems to be far from the reach of ordinary citizens under a bureaucratic and hierarchical government where sustainability-centred policy integration is rarely an issue. They went on to argue that it is unfortunate that policymakers commit to sustainability only in words, but often support non-sustainable behaviours. As sustainable governance depends on the credibility of the decision makers in different sectors at different levels and their decision-making processes, the authoritative power of government is seemingly more important. A previous study values governance as part of sustainability - as it is an interdisciplinary concept, sustainability in fact is rooted in both the physical and social sciences (Figure 1.1) (Linton et al., 2007). Linton and colleagues also argue that in the field of social science, the role of government and community, along with individual group behaviours within cultural norms, have been found to be an important factors of sustainability. In addition to Figure 1.1 (Linton et al., 2007), present study supplements a figure of interconnection among global, national, and supply chain management processes in Figure 1.2.

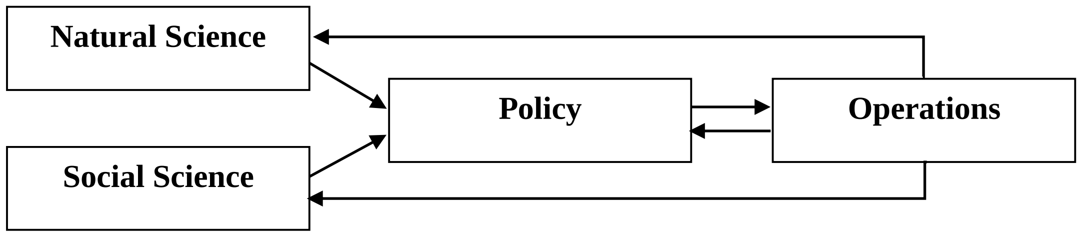

Figure 1.1 Relationship between different disciplines in the consideration of sustainable supply chains. Reprinted from "Sustainable supply chains: An introduction" Linton, J. D., Klassen, R., and Jayaraman, V., 2007, *Journal of Operations Management*, *25*, 1079.

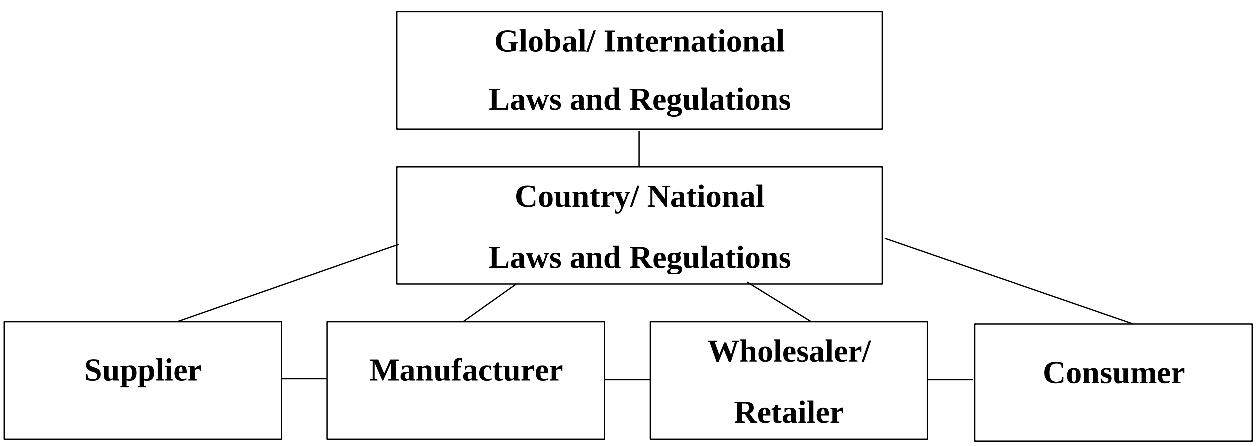

Figure 1.2 Sustainable Supply Chain Management in a Larger Context

The focus of this study rests on sustainability in supply chain management as the nature of SCM is becoming more challenging with shortened product life cycles, various products with increased customization, and geographically dispersed supply chain partners around the world (Bozarth et al., 2009). The global economic structure has changed over several decades, and the intervention of national and international policy and government are inevitable (Schott, & Jensen, 2008). Schott and Jensen (2008) point out that a number of governments are finding it difficult to be equally successful in devising international policies and in increasing the speed of the dynamic and competitive business environment, which in turn generates economic growth of a country. Choi, Dooley, and Rungtusanatham (2001) argue that managing dynamic and complex supply networks is frustrating and helpless due to the inevitable lack of prediction and control over – second- and third-tier suppliers that are often almost impossible to monitor from downstream. They divided the complex adaptive systems (CAS) of supply chain management into three parts: internal mechanisms, environment, and co-evolution. Among these, the environment is the external factors that affect organizations that are socio-economically and culturally connected. Then they divided the environment into the dynamic and rugged landscapes. They argue that constant adaption is needed under dynamism. A firm's goal of maximizing profit under circumstances of fast changing supply network (SN) of emergent, dynamic, and unpredictable is a big challenge for them. In 2002, Choi and Hong noted that the operation of a SN can vary depending on policies, practices, and culture.

Academia is aware that the political atmosphere and higher level of enforcement, such as government, of sustainability, are needed, but there are few studies done on the connection between county and corporate sustainability. Rather, much of the literature are focusing on adopting sustainability at business operation separated from government rules and regulations of the countries that their suppliers that supplies beyond direct suppliers are based on. Schott and Jensen (2008) points out that the importance of entrepreneurship is recognized globally for economic growth. They also claim that companies play different roles for different countries at different economic development stages. In other words, developed countries tend to be far superior in economic growth than the developing countries and those companies residing in highly developed countries benefits economically from county policies.

This thesis briefly examines sustainable supply chain management (SSCM) and different methods taken to measure sustainability at the national and company levels which leads to the methods to be used to connect sustainability of country and sustainability of corporates within the specific countries. Indicators that had been used by Bilbao-Terol (2014) are taken from the World Bank (the Adjusted Net Savings (ANS)), the Global Footprint Network (the Ecological Footprint (EF)), the Yale University (the Environmental Performance Index (EPI)), and the United Nations Development Program (the Human Development Index (HDI)). The Logistical Performance Index (LPI) taken from the World Bank is added to satisfy the supply chain management aspect along with the Worldwide Governance Indicators (WGI), which adds an aspect of level of good governance of each country. Analytic Hierarchy Process (AHP) and the Technique for Order Preferences by Similarity to Ideal Solution (TOPSIS) are used to give different weights to each criterion and rank countries in accodance with sustainability supply chain management indices.

Adoption of the sustainability concept has been embedded in various parts of supply chain management (SCM), and in different forms of strategies. Numerous companies and government organizations adopted diverse sustainability strategies such as lean management (LM), green supply chain management (GSCM), reverse supply chain management (RSCM), and third party certification systems such as environmental management systems (EMS) to achieve production and process improvement to compete with competitors under changing laws and regulations (Martínez-Jurado and Moyano-Fuentes, 2013). If traditional SCM's sustainability focused on the process of raw materials and its flow to downstream, then the future SCM sustainability should consider extending and integrating its focus on product design, manufacturing by-products, by-product produced during product use, product life extension, product end-of-life, and recovery processes at end-of-life (Linton to al., 2007, p. 1078).

Present work makes the following contributions to the growing field of SSCM. First, the "real world" data from major data collectors such as the World Bank, the Global Footprint Network, and the United Nations Development Programme are used to explain the current sustainability situation rather than use fictional numbers. Also all data are from publically available sources based on 2012 data except EF, as the most recent publically available data are from 2007. Second, the present study examines the connection between country sustainability and company sustainability. As supply chain management deals with all processes occurring within the supply chain, including decision making in purchasing, the comparison of country sustainability performance ranking (SPR) and industry SPR would give policymakers and decision-makers at both levels considerations on strategy and value towards their sustainability goals consistent with their own priority. As the method provided in this study is convenient and easy to implement in both academia and practice, it is highly applicable in both fields. Third, the TOPSIS model is used. This model is superior to a simple-scoring model as it adds one more step of measuring the distance from the positive and negative ideal solution to find the best score.

As there are currently few studies in sustainable supply chain management relating countries and industries, this study makes such a connection by using two methods called AHP and TOPSIS. Free statistical software R (3.2.0) and R-Studio is used on both AHP and TOPSIS to construct a SSCMI ranking based on equally weighted criteria and based on AHP criteria. Each data source constrains three different datasets called TBL, TBL+ LPI, and SSCMI. TBL include four indices including ANS, EF, EPI, and HDI, which are adopted by Bilbao-Terol (2014), TBL+LPI adds LPI to TBL, and SSCMI adds WGI to TBL+LPI. Both data based on equal weight and AHP are presented in world-map by using R-Studio, which gives geographical visualization of the results.

The following sections are structured as follows. Chapter II provides an overview of the literature review regarding sustainable supply chain management, country and corporate studies based on sustainability. Detailed index and data description follows along with analysis methods in Chapter III. Fundamental technique for both AHP and TOPSIS are explained in Chapter IV. Then applications using equal weight, AHP, and TOPSIS are done on country data based on sustainable supply chain management indices (SSCMI) and genuine corporate sustainability reports are studied in Chapter V. Chapter VI discusses further discussions, conclusion, and future research directions.

2 Scope of Research

This research addresses the following objectives:

(i) To observe similarity or difference of country sustainability and corporate sustainability based on supply chain management aspect

(ii) To have further understanding of sustainable supply chain management (Chapter II)

(iii) To understand previous studies done on sustainable supply chain management based on country and corporate (Chapter II)

(iv) To identify globally accepted indices and develop an sustainable supply chain management indicator (SSCMI) for countries (Chapter III)

(v) To study and understand AHP and TOPSIS (Chapter IV)

(vi) Apply Equal weights, AHP and TOPSIS to actual data by using R (3.2.0) and R Studio and compare the results (Chapter V)

(vii) Develop a world map based on country ranking by using R (3.2.0) and R Studio for visualization and compare the results (Chapter V)

(viii) Analyze real-world sustainability report of a company who shares global sustainability goal and guidance (Chapter V)

In this regard, the current study aims to achieve the followings:

1. Develop an indicator to quantify sustainability in supply chain management context
2. Extend the work of Bilbao-Terol et al. (2014) who attempted to measure sustainability within the context of triple bottom line using simple weights and TOPSIS approaches and the work of Wilson et al. (2007) who attempted to measure sustainability by using simple scoring model and to provide visual data description
3. Use mixed AHP-TOPSIS model to provide practical measurement on quantified sustainability within supply chain management context

CHAPTER II. LITERATURE REVIEW

Sustainable supply chain management is used as a wide-ranging concept including economic, environmental, and social. The aspect of sustainability with governance is adopted in this thesis. The idea of sustainable supply chain, however, is often mistakenly understood as other terminologies such as green supply chain management (GSCM) and reverse supply chain management (RSCM). This chapter explains the similarities and differences of sustainable supply chain management, green supply chain management (GSCM), and reverse supply chain management (RSCM). Previous research on sustainable supply chain management on both national and corporate level are explored as well. Finally, existing methods of measuring sustainable supply chain management are discussed.

2.1 Supply Chain Management (SCM) and Sustainable Supply Chain Management (SSCM)

Before starting a discussion of sustainable supply chain management (SSCM), the definition of supply chain management (SCM) needs to be clarified. The definition of SCM is often confused with the definition of logistics. It, however, is a collective term of entire business systems and strategy including sourcing, production, distribution, and service and Mentzer et al. (2001) clarifies the term SCM as:

> Supply chain management is defined as *the systemic*, *strategic coordination of the traditional business functions and the tactics across these business functions within a*

> *particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole. (p.18)*

SCM is beyond basic management of cost, quality, and delivery, but it needs to address a complex set of issues ranging from upstream to downstream through the whole supply chain. There are number of growing issues within the supply chain regarding social and environmental issues. Local, national, and international governmental agencies, neighbors, workers, not-for-profit groups, and other stakeholders force firms to practice more environmentally friendly processes and social care, not only in the firm itself, but also throughout their whole supply chain (Vachon and Klassen, 2006). To cope with rules and regulations and to satisfy customer expectations, firms are increasingly implementing voluntary environmentally friendly practices by adopting self-regulatory systems such as ISO 14001, Eco-Management and Audit Scheme (EMAS), and LEED certifications. However, it is hard to trace down numerous suppliers of firm's in the world of growing number of multinational and domestic corporations. Thus, sustainable direct suppliers do not necessarily mean whole supply chain is sustainable. Tracing sustainability throughout the whole supply chain is difficult and takes too much effort and time especially in dynamic and complex world of business, and putting too much efforts tracing every single supplier may cause a reduction in the firm performance.

The United Nations Global Compact (2010) defines sustainable supply chain management (SSCM) as "the management of environmental, social, and economic impacts, and the encouragement of good governance practices, throughout the life cycles of goods and services (pg. 5)", which "to create, protect and grow long-term environmental, social and economic value for all stakeholders involved in bringing products and services to market. (p. 7)". It also remarks that it is important that corporates integrate SSCM, first, to be in compliance with stronger laws and regulations of domestic and international business conduct. Adopting SSCM is also needed as customer awareness of sustainability is increasing. The companies who takes action to be better in social, economic, and environmental impacts benefit by doing so.

In addition to general Triple-Bottom-Line (TBL) concept of sustainability with environmental, social, and economic criteria, the concept of good governance seems to play a major role within SSCM. Spangenberg (2002) argues that the prism of sustainability is an interlinkage of four dimensions including economic, social, environmental, and institutional subsystems. The institutional subsystems embrace political organizations who are the actors that are able to facilitate societal orientations by structuring political behaviours and systems of rules, which, in fact, is the same as governance. According to Huther and Shah (1998), governance is "a multi-faceted concept encompassing all aspects of the exercise of authority through formal and informal institutions in the management of the resource endowment of a state (pg. 2)". Kemp, Parto, and Gibson (2005) argue that adoption of 'pillars' – a term similar to TBL and is used by many sustainability literatures - is insufficient due to its lack of interconnections and consideration of institutional aspects.

The United Nations Global Compact (2010) emphasizes the importance of looking beyond direct supplier relationships of companies; through risk management, operational efficiency, and sustainable products. It continues emphasizing the importance of integration of sustainability across the worldwide supply chain; supply management, design, development, production, logistics, marketing, and sales. Wu and Pagell (2011) argue that the decision making within supply chain is already complex enough with multiple uncertainties and unknown information across the supply chain, including their non-direct suppliers, global competition for resources, and tighter environmental regulations within and outside of their territorial boundary. Therefore, the companies are more in need of finding a way to balance both short-term profitability and long-term sustainability when making supply chain decisions under considerations of economic, environmental, social, and governance. Moreover, the role and responsibility of supply chain managers becomes more vital for these adoptions to be implemented. The risk and opportunities need to be determined carefully at multi-tiered operations within industry and under the laws and regulations of the country that the company resides in. Thus, this thesis considers four aspects of sustainability into SSCM; economic, environment, social, and governance.

2.2 Difference of Sustainable Supply Chain Management (SSCM), Green Supply Chain Management (GSCM), and Reverse Supply Chain Management (RSCM)

A number of research and practice are skewed towards environmental practices in SCM, and they are often confused with Green Supply Chain Management (GSCM). As mentioned above, SSCM embraces economic, environment, social, and governance aspect, but GSCM only concentrates on green, in other words, the environmental dimension of SCM. In fact, Ahi and Searcy (2013) regards SSCM as an extension of GSCM. And “Green supply chain management: Manufacturing - A Canadian perspective” (Industry Canada, 2009) comments that GSCM incorporates “environmental” rationals into SCM including; *energy efficiency, reduction of greenhouse gas (GHG) emission, water conservation or processing, waste reduction, reduced packaging/increasing use of biodegradable packaging, product and packaging recycling/re-use,* *and green procurement practices* (page 4). It does not comprise any of social, economic, or governance aspects. Thus, the GSCM should not be mistaken with SSCM nor interchangeably used. Reverse Supply Chain Management (RSCM) is considered as one of the important tools to achieve business sustainability in the long run for societal, environmental and economic success. The need and importance of RSCM is growing within and outside of business and becomes popular with the rising concern for environmental issues of a "throw-away society" (Dekker et al., 1998, p. 141). In 2003, Norek finds that the overall value of returned goods in general is estimated to be around $43 billion per year, representing an average of 15% - 20% of all goods sold. He also points out that this can be improved by 10 to 15% by using the right supply chain process, such as proper supplier selection, implementation of proper RSCM processes, thorough inspection at inventory

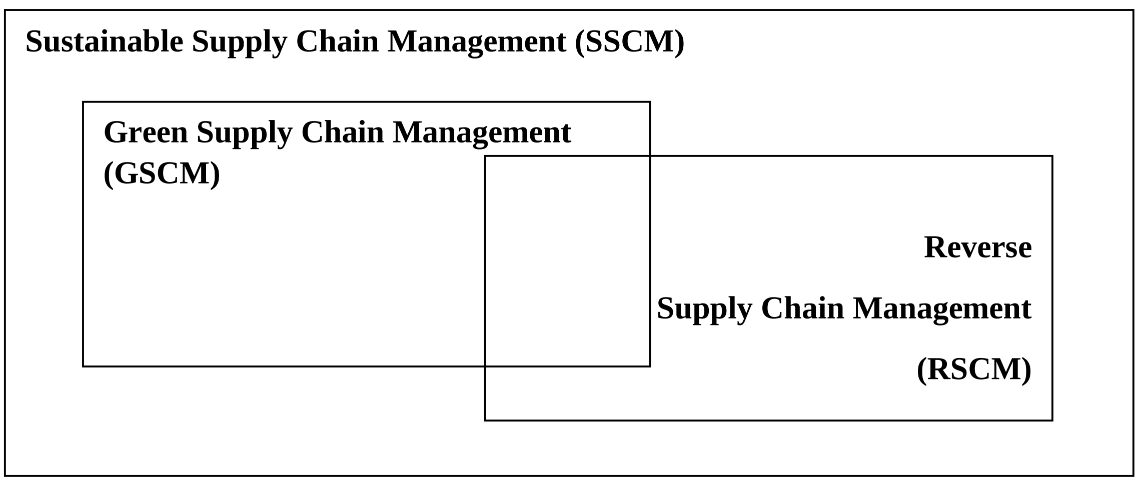

Figure 2.1 Sustainable Supply Chain Management, Green Supply Chain Management, and Reverse Supply Chain Management

level, and improved handling of missing information. These adoption of appropriate processes would result in increased asset recovery, reduced labour and inventory costs, along with increased customer satisfaction (Norek, 2003) – all of which are beneficial to a firm's longer-term sustainability and also help long term sustainability for future generation. (See Figure 2.1 for better understanding).

2.3 Different Modelling Approach towards Sustainable Supply Chain Management

While governments and companies tried to improve the environmental impact of their products or processes, at the same time as improving their economic benefits in practice by adopting some of academia's effort, scholars put a lot of effort into both qualitative and quantitative approaches in SSCM (Wu, Liao, Tseng, and Chiu, 2015).

Since the early 20th century, there has been an increasing number of journal articles published regarding sustainable supply chain management issues (Linton et al., 2007; Hassini, Surti, & Searcy, 2012; Seuring, 2013). Scholars wanted to determine whether various sustainability adoptions in different sectors of SCM are effective or not, and if they are, and by how much. Hassini *et al.* (2012) reviewed 707 papers on sustainable supply chains between 2000 and 2010. They categorized papers according to industry sector, firm size and sustainability, research methods, supply chain drivers, and supply chain partners. Within research methods, 36 out of 87 papers applied methodological, Analytic, and mathematical approaches followed by 19 case study, 18 reviews, and 14 empirical model papers. The methodologies used included optimization concepts, Analytic Hierarchy Process (AHP), Fuzzy decision making, heuristics, simulation, and exergoeconomics. The majority of the reviewed papers concentrated on corporate level operations rather than looking at broader political atmosphere.

A literature review by Seuring and Müller (2008) constructs a conceptual framework for sustainable supply chain management. Out of 191 papers published between 1994 and 2007, 140 were related to the environmental realm; 20 were related to social; and 31 were related to sustainability, including both environmental and social aspects. The review also took methodologies into an account. Within 191 papers, 70 were based on case studies, 53 were on survey, 40 were on theory and conceptual work, 21 were on modeling and 7 were literature review papers. Based on the reviewed papers, they found that external pressure is one of the motivations for companies to adopt sustainable operations including pressures from government, customer, and other stakeholders. When the external pressure passes onto the company, it again passes on to their direct and indirect suppliers – in other words, to whole supply chain systems.

Seuring (2013) reviewed modeling approach papers published in 2008 within the concept of SSCM followed by a literature review on sustainable supply chain management (Seuring and Müller, 2008). He found that there were only 36 quantitative model papers out of more than 300 papers dealing with green or sustainable supply chains, which were published up to the end of 2010. He also categorized the papers into life-cycle assessment based models (LCA), equilibrium models, multi-criteria decision making (MCDM), and applications of the Analytic hierarchy process (AHP). MCDM papers were found the least with only six papers were related to SSCM. Also most of the empirical research presented in the papers were focused on theoretical or numerical examples (77.8%), which were "made up", followed by a few papers with statistical data (13.9%), empirical data (5.5%) and no data (2.8%).

Some scholars focused on corporate level of research regarding SSCM. Schmidt and Schwegler (2008) proposed value-based cumulative eco-intensity (CEI), which measures environment or sustainability performance of a company and its direct suppliers. The advantage of CEI is that the information gathering is inexpensive, quick, and simple as it needs information only for its own company and its direct suppliers. It also points the way to optimize the environmental burden benefit and also finds the environmental performance of a company's entire product range rather than for the single product. The limitation of this method is that all participants, i.e. company and direct suppliers, should have uniform regulations in order to balance and measure indicator. This is a challenging, especially on an international level. There also is a restriction that all participants need to depend on each other for recursive calculation.

Govindan, Khodaverdi, and Jafarian (2013) apply the fuzzy multi-criteria decision making (MCDM) approach for supplier selection/ evaluation based on TBL concept. They use a fuzzy TOPSIS to aggregate the ratings for each supplier and generate an overall sustainability performance score for each supplier in order to choose the best supplier among the candidates. They propose not only the buyer, but the suppliers themselves can use this methodology in order to compare themselves to competitors to develop better products and processes as well as reduce the negative environmental and social impacts by identifying and prioritizing opportunities for sustainability performance improvements. The limitation of this research is that it does not engage with higher-level government policies that decision makers within the company would be pressured on regulation-wise depending on the residing country.

One of the most recent attempts of sustainability measurement is made by integrating fuzzy set theory and the decision-making trial and evaluation laboratory (DEMATEL) method to scrutinize the effect of each criterion within green supply chain practices (GSCP) by using case study. As result of the research, it suggests to Vietnamese automobile industry to integrate reverse logistics system internally and externally in order to reduce environmental issues, waste treatment cost, and energy consumptions and imposes those changes would improve firm’s environmental image as well as competitive advantage among its competitors. One of the limitation again is that it only considers SSCM at the industry level, especially the focus is on the automotive manufacturer in Vietnam.

2.4 Sustainable Supply Chain Management at the National Level

While the government and companies tried to improve environmental impact of their product or process, much emphasis is put on improving their economic benefits and social responsibility in practice by adopting academia's effort. In contrast, scholars put much efforts into both qualitative and quantitative approaches in SSCM (Wu, Liao, Tseng, and Chiu, 2015).

There are few journals or articles found in SSCM that much focuses on country level SSCM, but Vachon and Mao (2008)'s study is one of the SSCM related articles that does so. The study tries to demonstrate a link between supply chain characteristics including supply chain strength and sustainable development at the national level. With Environmental Sustainability Index (ESI), it tests the relationship between a country's supply chain strength and three different dimensions of sustainability: general country's environmental performance, corporate environmental practices within the country, and social sustainability. The definition of the supply chain strength is given as "the availability and quality of the organizations along the supply chain, as well as the value added by the interaction among them" (Vachon and Mao, 2008). It argues that academia and practice pay little attention to the linkage of country's industrial profile and its sustainable development efforts and outcomes of industry. However, the result shows supply chain strength, which correlates with sustainable development, actually seems to favour economic growth; in other words, the trade-off between economic improvements and efforts on sustainability does not exist. With its results, this thesis supports the argument that the companies with better SSCM systems throughout direct and indirect supply chain have better local and global social and environmental involvement, which also leads to economic benefit with supporting customers and stakeholders.

2.5 Sustainable Supply Chain Management at Company Level

SSCM is increasingly recognized as a key concept of domestic and international corporate responsibility. Increasing attention to SSCM is not only in a right direct for common good but also make a way for prevalence in dynamic changes in domestic and international laws and regulations. Many corporates in the current complex world adopt various systems and strategies to comply with local and global restrictions. As Wu and Pagell (2011) point out, there is an increasing recognition of sustainable development and triple bottom line. The evidence for this trend is in implementation of third party certifications of Environmental Management System (EMS), such as ISO 14000 family and Eco-Management and Audit Scheme (EMAS). These certifications help organizations to evaluate, report, and improve the environmental performance voluntarily. Service industries, such as banks, adopt LEED certification to their buildings. However, as implementation of such programs requires the feasible sacrifice of a company's resources such as time, money, and human resources. Hence, such certification or programs are often not applicable for smaller sized companies who are not able to commit disproportionate financial or human resource sacrifice (Campos, 2012). Martín-Peña, M. L., Díaz-Garrido, E., & Sánchez-López, J. M. (2014) identified twelve commonly analyzed benefits from other literature. First is an improvement in product and/or service quality by stressing the importance of it at the training introduction. Such practice in turn enhance their market share. Second is an improvement in employees' motivation and performance and managers' motivation by encouraging new interactions between them and improve satisfaction for both parties. Third is cost reduction and improvement in productivity and efficiency. Fourth is an improvement in competitive position by eliminating waste and substituting non-additive value. Fifth is firm's ability to attract new markets and customers, and at the same time of achieving customer satisfaction. Sixth is an improvement in firm's image in the market.

Seventh is an improvement in relations with stakeholders including investors, insurance companies, and employees. Eighth, it makes better access to sources of finance by increasing funding opportunities with growing consideration of sustainability practices. Ninth is the firm's compliance with environmental regulations which reduces liabilities as well as fines and sanctions. Tenth is improvement in environmental performance including reduction in air emissions, waste and water, and energy and materials use. Lastly, companies benefit in improvements in operational processes by adopting clean technologies. Even with all above benefits that firms acquire by adopting EMS, it is difficult adopting them. Martín-Peña, M. L., Díaz-Garrido, E., & Sánchez-López, J. M. (2014) also identified and summarized those difficulties that prevent firms from adopting environmental measures. One of the majority difficulties in adopting EMS is the cost of adopting it. The cost does not only include financial cost such as an auditor fee, but also includes time, effort, and human resources that are put into the process of adopting EMS (Campos, 2012). The other reason for difficulties is the complexity and lack of harmony in national and international environmental legislation. Those differences make firms' implementation of EMS long and those national and international laws and regulations change fast in a dynamic world, which again makes the implementation slow. The lack of understanding and importance of implementing EMS and lacking of commitment to the environment along with the low level of communication, training, and qualifications are internal difficulties of EMS implementation.

Before explaining ISO 14000, International Organization for Standardization (ISO) needs to be explained. According to iso.com, ISO is a non-governmental organization with 162 member countries around the world. ISO has more than 19500 standards over almost all aspects of daily life to meet the needs of stakeholders such as business, industry, governmental authorities, non-governmental organizations, and consumers (*Environmental Management: The ISO 14000 family* *of International Standards,* 2009). It also mentions that it was created to ensure safe, reliable, and quality of products by reducing cost, minimizing waste and error, and increasing productivity of business internationally. It claims that adopting such standardization helps to access new markets and to facilitate free and fair global trade. ISO 14000 family is one of the widely known environmental certification and is used worldwide (Rondinelli & Vastag, 2000; Wiengarten, Pagell, & Fynes, 2013). It is often used along with ISO 9000, a quality management system, and it is often called ISO MSS (Castka & Balzarova, 2008). Plan-Do-Check-Act (PDCA) has been added to ISO 14000 protocol along with ISO 9000. According to Environmental Management, 2009, there are several economic and environmental benefits by implementing ISO 14000 standards encompassing sustainable development and the triple bottom line; reducing usage of raw material, reducing energy consumption, improving process efficiency, reducing waste generation and disposal costs, and utilization of recoverable resources. Among ISO 14000 protocols, ISO 14001 is one of the world's most recognized frameworks, which has been adopted by more than half of the national members. ISO 14001 is not only apply to internal operations, but throughout firm's whole supply chain as well (Nawrocka, Brorson, & Lindhqvist, 2009). A number of firms who implemented and certified ISO 14001, however, are still mostly focusing on direct impacts and less on indirect impacts especially direct financial impacts. Vachon and Mao (2008) found that statistically, ISO 14001 adoption and implementation strengthens the network of suppliers and customers more richer, proactive in environmental management, which in turn can be a competitive advantage over competitors.

It is becoming more important for companies around the globe to operate in operational practices in line with environmental, social, physical, biological, and of course financial benefits (Phillis and Davis, 2009). Phillis and Davis (2009) summarize good reasons for companies to adopt sustainability. First is that adaptation for sustainable practices is good marketing. Consumers are more willing to buy products from more environmental friendly and socially responsible companies. Second is that such adaptation is in compliance with government's goal and regulation of sustainability. Companies ought to comply with laws and regulations set by the government. Meeting those regulations and government limitations often are beneficial for both parties. Also, in the long run, implementing sustainability concept to corporate effects financial and economic performance of the firm positively. Sustainability adoption also makes firms look better on papers by complying with regional, national, and international laws and regulations concerning social and environmental aspects such as pollution, recycling, and labour. By publishing a sustainability report, firm expose their progress, guidance, goals, and strategies to give perspectives internal and external stakeholders.

Within the discretion of supply chain management, sustainability relationship between country and corporate is considered less than in other disciplines. Inn 2001, Bradley (2001) published a journal in marketing aspect studying country-of-origin effect. He argues that there exist interaction of country effect and company effect and found that the 'made in' labels affect customer when buying products. This thesis is focusing on the ranking of countries based on internationally accepted indices based on SSCM aspect. Then a company case study is conducted, try to compare the result with the company ranking.

The following section describes indices that are publically available. These real-life data collected from reliable organizations help in understanding of practical problems that world is facing. There are more indices developed by relating supply chain management indices along with sustainable development indices that are later used in application to real-world data.

CHAPTER III. INDICES AND DATA DESCRIPTION

3.1 Sustainable Supply Chain Management Indices (SSCMI)

This thesis defines a new terminology called sustainable supply chain management indices (SSCMI). SSCMI include total of six indices. The most commonly used indices which are used by Bilbao-Terol et al. (2014) – the Adjusted Net Savings (ANS), the Ecological Footprint (EF), the Environmental Performance Index (EPI), and the Human Development Index (HDI) are adopted. Additions to these general sustainability indices, the Logistics Performance Index (LPI) and the Worldwide Governance Indicators (WGI) have been added. LPI has been added to supplement supply chain management characteristic, and WGI has been adopted on behalf of the level of government effectiveness. Detailed explanations of each index follow. All indices are publically available at no cost from several sources such as the World Bank, the Footprint Network, and the United Nations. This study is based on 2012 data available at the time of this thesis, except for the EF which the 2007 EF data is the most recent publically available data at no cost.

3.1.1 Adjusted Net Savings (ANS)

The According to the World Bank definition [20], as one of the indicators of macroeconomic performance, ANS provides a country's sustainability measurement by measuring the change in comprehensive wealth during a particular accounting period. It measures the financial capital of countries as well as the changes in natural resources and human capital that the present generations are renting from the future generations. There are two measurements, one including particulate emission damage and the other without it. This study uses ANS data including particulate emission damage including concentration levels, does-response relationship, baseline mortality and morbidity data, and the value of a statistical life, and relates these measurements to sustainability (The United Nations, Adjusted net saving as a percentage of gross national income). Out of 248 countries, 137 countries have ANS data, representing approximately 55.24% of countries the World Bank has listed. ANS is used over Gross Domestic Product (GDP) as it is more relevant to sustainable development's economic benefit, environmental, and social justice aspect. According to economic theory, social welfare increases when a country's ANS is positive and on the other hand when the ANS is persistently negative, then it means the country's economy is on an unsustainable path. Note that the following measurement is measured by a percentage of gross national income (GNI), which is the aggregate value of the balances of gross primary incomes for all sectors, and is identical to gross national product (GNP) (The United Nations. GNI):

$$ANS = GNS - D - CSE - \sum R_i - CD - PE$$

where

ANS = the Adjusted Net Savings

GNS = the Gross National Savings

D = the Consumption of fixed capital

CSE = the Education expenditure

$\sum R_i$ = the sum of Energy, Mineral, and Net forest depletion

CD = Damage from Carbon Dioxide emissions

PE = Damage from Particulate emissions

3.1.2 Ecological Footprint (EF)

According to Borucke *et al.* (2013), the first attempt to measure the ecological footprint (EF) began in 1997. The Global Footprint Network initiated its program in 2003 - National Footprint Accounts (NFAs) is a framework quantifying the annual supply and demand of key ecosystem services. It defines the EF as "a measure of the demand populations and activities place on the biosphere in a given year, given the prevailing technology and resource management of that year". This indicator fits into one of the sustainable development's element, environmental aspect. EF is an accurate and effective resource accounting system, which was designed to track the human demand on the regenerative and absorptive capacity of the biosphere and it can help nations, cities, and companies to be competitive. Global Footprint Network maintains and updates NFAs annually, and EF values are back calculated from the most recent year with improved methodologies. The following methodology is adopted from 2012 edition (p 6).

$$EF = \sum_i \frac{P_{N,i,j}}{Y_{N,i,j}} \cdot YF_{N,i,j} \cdot IYF_{W,i,j} \cdot EQF_{i,j} = \sum_i \frac{P_{N,i,j}}{Y_{W,i,j}} \cdot IYF_{W,\mathrm{i},\mathrm{j}} \cdot EQF_{i,j}$$

where

i = the product type

j = the given year

$P_{N,i,j}$ = the country-specific amount of each primary product i that is harvested in given year j (or carbon dioxide emitted) in the nation

$Y_{N,i,j}$ = the annual national average yield for the production of commodity i in given year j (or its carbon uptake capacity in cases where P is CO_2)

$YF_{N,i,j}$ = the country-specific yield factor for the production of each product i in given year j

$EQF_{i,j}$ = the equivalence factor for the land use type producing product in given year j.

$IYF_{W,i,j}$ = the world intertemporal yield factor for any given land type producing products i, in a given year j

$Y_{W,i,j}$ = the average world yield for commodity i in given year j

Note that the unit of above variables is based on global hectares (gha).

3.1.3 Environmental Performance Index (EPI)

The Environmental performance index (EPI) developed by Yale University with a goal of better responding to policy needs and objectives, is an outcome-oriented performance index as its predecessor environmental sustainability index (ESI). EPI, which satisfies the environmental aspect of sustainable development, enables the global community to track changes in performance of both environmental public health and ecosystem vitality policy categories. The 2012 EPI measures 132 countries in the following ten policy categories on 22 performance indicators: Environmental burden of disease, water (effects on human health), air pollution (effects on human health), air pollution (ecosystem effects), water resources (ecosystem effects), biodiversity and habitat, forestry, fisheries, agriculture, and climate change. According to Bilbao-Terol (2014), the EPI is based on a proximity-to-target methodology with the minimum value of 0 and the maximum value of 100 by normalization.

$$EPI = \frac{\text{international range - distance to target}}{\text{international range}} \times 100$$

3.1.4 Human Development Index (HDI)

The Human development index (HDI) is published by the United Nations Development Programme's Human Development reports almost every year and supplements the social aspect of sustainable development. According to the 2013 United Nations Human Development Programme where Malik *et al.* (2013) participated, HDI is a summary measure of achievements in key dimensions of human development, which are a health, education, and standard of living. The dimensions are then normalized and form a geometric mean, which becomes the HDI. The formulation from Malik et al. (2013) follows as below:

$$HDI = \sqrt[3]{I_{Health} \cdot I_{Education} \cdot I_{Income}}$$

where

I_{Health} = the life expectancy at birth in years

$I_{Education}$ = the mean number of mean years of schooling index and expected years of schooling index

I_{Income} = Gross national income per capita (PPP 2011 $)

3.1.5 Logistics Performance Index (LPI)

The Logistics Performance Index (LPI) is added to this thesis to supplement the supply chain aspect to the common sustainability aspect with TBL concepts. Arvis *et al.* (2012) argue that globally, policymakers recognize the logistics sector as one of their key contributing factor for development. Several European countries are leading the sustainable logistics. Since 2007, the World Bank publishes LPI reporting, including trade, customs, and transportation matters, every two years. As SC becomes more dynamic and complex with globalization, the efficiency of logistics within SC became more dependant on government services, investments, and policies, especially in the area of building infrastructure, regulatory development, and designing and implementing efficient customs clearance procedures. This indicator is simple and easy to use. There are two types of LPI database, one with the international LPI and the other with the domestic LPI. Since we want to compare different countries with each indicator, this thesis uses the international LPI data. It is a summary indicator of logistics (a single aggregate measure) combining six different indicators:

1. The efficiency of customs and border clearance
2. The quality of trade and transport infrastructure
3. The ease of arranging competitively priced shipments
4. The competence and quality of logistics services
5. The ability to track and trace consignments
6. The frequency with which shipments reach consignees within scheduled or expected delivery times

All components range between 1 and 5; where 1 being bad or low, and 5 being good or high, and are based on a survey of randomly selected groups in eight selected countries, which are chosen based on the most important export and import markets of the country. This indicator adds essence not only of SC in SSCMI but also the governance aspect to it as well with such LPI largely depends on government interventions.

3.1.6 Worldwide Governance Indicators (WGI)

According to Kaufmann, Kraay, and Mastuzzi (2010), the Worldwide Governance Indicators (WGI) consist of six combinations of indicators covering over 200 countries since 1996. The data are obtained from 31 different data sources such as survey respondents, non-governmental organizations, commercial business information providers, and public sector organizations worldwide about the governance perceptions of each country. Kaufmann *et al.* also mentioned that this data are highly useful and practical to use as they summarize the large and disparate set of distinct perceptions-based governance indicators since the 1990s.

The six indicators are defined as follows (Kaufmann, Kraay, & Mastuzzi, 2010. pg. 4):

1. Voice and Accountability (VA) – capturing perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media
2. Political Stability and Absence of Violence/Terrorism (PV) – capturing perceptions of the likelihood that the government will be destabilized or overthrown by unconstitutional or violent means, including politically-motivated violence and terrorism

3. Government Effectiveness (GE) – capturing perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies
4. Regulatory Quality (RQ) – capturing perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development
5. Rule of Law (RL) – capturing perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence
6. Control of Corruption (CC) – capturing perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests

A statistical measure known as an unobserved components model (UCM) was also provided by Kaufmann, Kraay, and Mastuzzi (2010). First, they assumed that a linear function can be written with unobserved and observed governance in country j.

$$y_{jk} = \alpha_k + \beta_k \left(g_j + \varepsilon_{jk} \right)$$

where,

y_{jk} : observed data from source k for country j

α_k and β_k : parameters which map unobserved governance in country j

g_j : normally distributed random variable with mean zero and variance one

ε_{jk} : the disturbance term, normally distributed with zero mean and same variance across countries, but differs across indicators i. e. $E\left[\varepsilon_{jk}\varepsilon_{jm}\right]=0$ and $V\left[\varepsilon_{jk}\right]=\sigma_k^2$ for source m different from source k

Given above formula, they define the mean as

$$E\left[g_j \mid y_{j1}, \ldots, y_{jK}\right]=\sum_{k=1}^{K} w_k \frac{y_{jk}-\alpha_k}{\beta_k}$$

, which is a weighted average of the rescaled scores for each country, $\frac{y_{jk}-\alpha_k}{\beta_k}$

where

w_k : weights assigned to each source k , $w_k=\frac{\sigma_k^{-2}}{1+\sum_{k=1}^{K}\sigma_k^{-2}}$

The standard deviation, in other words, an unavoidable uncertainty, is

$$SD\left[g_j \mid y_{j1}, \ldots, y_{jK}\right]=\left(1+\sum_{k=1}^{K}\sigma_k^{-2}\right)^{-\frac{1}{2}}$$

, which means the larger K (more data sources) is, the smaller is σ_k^2 (more precise individual data sources are).

Kemp, Parto, and Gibson (2005) connects the governance and sustainability by arguing that “governance and sustainable development are children of similar history and parentage” (pg.

13). They also argue that the governance is different from governing because the effectiveness of governance is coming from knowledge resources, money, and rights throughout the complex network of actors. They continue to argue that it is similar to complex system approach among social, economic, and environmental interrelationships with complexity and uncertainties with the need for flexibility and adaptive capacity. They argue that there is a need “to establish governance structures and practices that can foster, guide, and coordinate positive work by host of actors on a vast complex of issues, through webs of interconnection and across multiple levels and scales, with sensitivity to their contexts and respect for uncertainties” (pg. 26) for progress towards sustainability and with this reason, this thesis include WGI as one of the indices of SSCMI.

CHAPTER IV. METHODS

In this thesis, two of Multi-criteria decision making (MCDM) processes, Analytic Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), are used in the applications chapter. These methods will help decision makers to select the best supplier or buyer who meets better sustainability requirements. According to Senthil, Srirangacharyulu, and Ramesh (2012), MCDM, a decision matrix, consists of three main parts: *a) alternatives, b) criteria, and c) weights of relative importance.* Although AHP can be used as decision-making method itself, it can be used as a support tool when it combines with other decision-making methodologies, such as TOPSIS, to draw better solution (Senthil, Srirangacharyulu, and Ramesh (2012)).

4.1 Analytic Hierarchy Process (AHP)

According to Saaty & Vargas (2012), Analytic Hierarchy Process (AHP) is a basic and general measurement theory for decision-making that selects the best decision alternatives when dealing with multiple objectives or criteria. Even with disagreeing scholars doubting the "correctness" of using AHP, it gives a basic rationale for developing priorities when there is a hierarchy of criteria for choosing. According to Harker and Vargas (1987), AHP process is as follows (pg. 1384):

1. The decomposition principle calls for structuring the hierarchy to capture the basic elements of the problem;

2. The principle of comparative judgment calls for setting up a matrix to carry out pairwise comparisons of the relative importance of the elements in a level with respect to the elements in the level immediately above it;
3. The matrix is used to generate a ratio scale; and
4. The principle of synthesis of priorities is used to generate the global or composite priority of the elements at the lowest level of the hierarchy.

The 1 to 9 scale in a pairwise comparison of AHP, developed by Saaty in 1970's, captures the information of individual preferences and forms a matrix with the ratio scale and gives an independent scale. AHP is considered as a strongly nonlinear measurement even though it includes eigenvector and normalization procedures. The AHP method is a simple, but powerful decision-making tool, which does not require complicated standardization of an entire set of criterion, by using standard ratio scale form. The summary of AHP definition done by Appadoo, Hemarathne, Bector, and Thavaneswaran (2015) is well organized (pg. 2 and 3) and is explained as follows:

Definition 1.1 *An eigenvector of a square* $n \times n$ *matrix* A *is a vector* W *such that*

$$AW = \lambda W$$

where W *is a non-zero vector as the eigenvector of* A *and* λ *is the corresponding value, and* λ *can be real or imaginary.*

Definition 1.2 *The rank of a matrix A is defined as the number of linearly independent columns of the matrix* A *and the matrix of rank one has exactly one nonzero eigenvalue.*

Definition 1.3 *The trace of some matrix* A*, denoted as* $Tr(A)$*, is the sum of the entries in the diagonal. The trace of a matrix is also defined as the sum of its eigenvalues.*

Definition 1.4 *An eigenvalue of a square* $n \times n$ *matrix* A *is the scalar* λ *associated with an eigenvector* W *.*

Definition 1.5 *A consistent matrix is one in which for every entry* a_{ij} *(the entry in the* i^{th} *row and* j^{th} *column),* $a_{ij} = \frac{a_{kj}}{a_{ki}}$ *.*

Definition 1.6 *The principal eigenvalue, denoted* $\lambda_{\max}$ *, of a matrix is the largest eigenvalue of that matrix. The eigenvector method also yields a measure for inconsistency. The degree of inconsistency is measured by the principal eigenvalue* $\lambda_{\max}$ *.*

If A *is a pairwise comparison matrix of the size* n *, it can be shown that* $\lambda_{\max} > n$ *and* A *is consistent if and only if* $\lambda_{\max} = n$ *. Hence, one sees the consistency of a pairwise* $n \times n$ *comparison matrix* A *by the quantity* $\lambda_{\max} - n$ *.*

Definition 1.7 *Let* $A = \left(a_{ij}\right)$ *be an* $n \times n$ *real matrix.* A *is said to be positive provided that* $a_{ij} > 0$ *for all* $i, j = 1, \ldots, n$ *.*

Definition 1.8 *A reciprocal matrix is one in which for each entry* a_{ij} *,* $a_{ji} = \frac{1}{a_{ij}}$ *(reciprocity).*

Hence, a positive reciprocal matrix has a form such as

$$A = \begin{pmatrix} 1 & a_{12} & \cdots & a_{1n} \\ \frac{1}{a_{12}} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \cdots & 1 \end{pmatrix}$$

Definition 1.9 *Let* $A = (a_{ij})$ *be an* $n \times n$ *positive reciprocal matrix.* A *is said to be consistent (with Saaty's inconsistency) provided that* $a_{ij} \cdot a_{jk} = a_{ik}$ *(transitivity) for all* $i, j, k = 1, \ldots, n$*. Thus, a pairwise comparison matrix is called consistent if the transitivity and the reciprocity rules are respected.*

Definition 1. 10 *The consistency index (CI) for a pairwise comparison matrix* A *is the numerical value*

$$CI = \frac{\text{Principal eigenvalue} - \text{size of matrix}}{\text{size of matrix} - 1} = \frac{\lambda_{\max} - n}{n - 1}$$

The numerator $\lambda_{\max} - n$ *measures how far the principal eigenvalue is from the consistent case. We divide* $(\lambda_{\max} - n)$ *by* $n - 1$*, which gives us an average of the other* $n - 1$ *eigenvalues of our pairwise comparison matrix. Note that the consistency index* CI *is not uniquely defined.*

Using above the definitions, Appadoo, Hemarathne, Bector, and Thavaneswaran (2015) explain the calculation method for AHP as follows:

First, Let $C_1, C_2, \ldots, C_i, \ldots, C_j, \ldots, C_n$ *denote the* n *different criteria to be considered in a Multiple Criteria Decision Making (MCDM) problem. Our objective is to find the weights* $w_1, w_2, \ldots, w_i, \ldots, w_j, \ldots, w_n$ *given the pairwise comparison matrix* A*. Let* a_{ij}*, where* $i, j = 1, 2, \ldots, n$*, be the elements of* C_i *when compared with* C_j *and the matrix* A *be denoted by*

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1j} & \cdots & a_{1n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ a_{i1} & a_{i2} & \cdots & a_{ij} & \cdots & a_{in} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nj} & \cdots & a_{nn} \end{bmatrix}$$

where $a_{ji} = \frac{1}{a_{ij}}$ *. If the judgement* $\int_0^1 xn(n-1)\,dx$ *are perfect in all comparisons, then* $a_{ik} = a_{ij} \cdot a_{jk}$ *for all* $i,\ j,\ k$ *and by the definition of consistency, we refer to the matrix* A *as being a consistent matrix. An obvious case of a consistent matrix* A *is when its elements* $a_{ij} = {w_i}/{w_j}$ *, where* $i,\ j = 1,\ 2,\ \ldots,\ n$ *. Thus, when matrix* A *is multiplied by the weighting vector given by* $w = (w_1,\ w_2,\ \ldots,\ w_n)^T$ *, one gets:*

$$AW = \begin{bmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_j & \cdots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \cdots & w_2/w_j & \cdots & w_2/w_n \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ w_i/w_1 & w_i/w_2 & \cdots & w_i/w_j & \cdots & w_i/w_n \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ w_n/w_1 & w_n/w_2 & \cdots & w_n/w_j & \cdots & w_n/w_n \end{bmatrix}_{n\times n} \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_j \\ \vdots \\ w_n \end{bmatrix}_{n\times n} = n \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_j \\ \vdots \\ w_n \end{bmatrix}_{n\times 1} = nW$$

Note that a_{ij} *is the subjective rating given by the decision-makers. The difference between consistent case and the actual values is* w_i/w_j *, then*

$$AW = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1j} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2j} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ 1/a_{1j} & 1/a_{2j} & \cdots & 1 & \cdots & a_{jn} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1/a_{jn} & \cdots & 1 \end{bmatrix}_{n\times n} \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_j \\ \vdots \\ w_n \end{bmatrix}_{n\times n} = \lambda_{\max} \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_j \\ \vdots \\ w_n \end{bmatrix}_{n\times 1} = \lambda_{\max} W$$

Thus, $AW = nW$ *cannot be calculated directly. Therefore Saaty and Vargas (2012) suggested using the maximum eigenvalue,* $\lambda_{\max}$ *of the solution of matrix* A *to replace* n *, yields* $AW = \lambda_{\max} W$ *. By this method, one can obtain the characteristic vector, referred to as the priority vector in the AHP literature.*

The above AHP method is used in a later analysis to give weight to each criterion. As it is given discrete Saaty's scale, this thesis uses one of the most common weighting method: Normalization of Row Average (NRA) as summarized in Appadoo, Hemarathne, Bector, and Thavaneswaran (2015; pg. 6).

a) *As shown in Gao, Zhang, and Cao (2009),* each row's elements are summed up and standardized by summing all elements of the matrix as below.

$$w_i = \frac{\sum_{j=1}^{n} a_{ij}}{\sum_{i=1}^{n} \left(\sum_{j=1}^{n} a_{ij} \right)}, \qquad i = 1, 2, \ldots, n$$

b) *Let* $A = (a_{ij})$ *be an* $n \times n$ *pairwise comparison matrix. The process of finding the priority weights are as follows. First, we normalize the column vectors in the judging matrix, then add the normalized matrix in rows. This approach is normally referred to* *as the sum method in the AHP literature. The result is normalized again to get the eigenvector:*

$$w_i = \frac{1}{n}\sum_{j=1}^{n}\left(\frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}\right)$$

c) *The eigenvalue method, which is usually referred to as EM in Satty and Vergas (2012), is known to uniquely capture transitivity in inconsistent matrices. The priority vector derived from EM is denoted by* $W = (w_1, w_2, \ldots, w_n)^T$. *The judgment matrix is denoted as* $A = (a_{ij})$, $a_{ji} = \frac{1}{a_{ij}}$, $a_{ij} > 0$, $i, j = 1, 2, \ldots, n$. *EM solves for the principal eigenvector in* $AW = \lambda_{\max} W$, *where* $\lambda_{\max}$ *is the principal eigenvalue of* A. *The EM solution is given by Gao, Zhang, and Cao (2009) as*

$$w = \lim_{k \to \infty}\left(\frac{A^k e^T}{eA^k e^T}\right)$$

where $e = (1, 1, 1, \ldots, 1)$. *It consists in taking as weights of components of the (right) eigenvector of the matrix* A. *Therefore the eigenvector is defined by*

$$AW = \lambda_{\max} W$$

where $\lambda_{\max}$ *is the largest eigenvalue of* A. *It must be noted that this eigenvector solution is normalized additively, i.e.* $\sum_{i=1}^{n} w_i = 1$.

Opinions differ, and some scholars question the subjective judgment of the cognitive environment. Those who criticize AHP, according to Harker and Vargas (1987), question whether the terms such as “more important” or “strongly more important” can be different from one to another, but Harker and Vargas (1987) deny their criticism as AHP is based on a firm theoretical foundation and therefore is viable and usable decision-making tool.

A simple example is presented in Appadoo et al., 2015 (Pg. 7):

Consider the pairwise comparison matrix given below,

$$A=\begin{bmatrix} 1 & \frac{1}{8} & \frac{1}{4} \\ 8 & 1 & \frac{1}{5} \\ 4 & 5 & 1 \end{bmatrix}$$

To compute the priority weights, we normalize each of the rows by dividing by the sum of the column, then averaging each of the rows to get the priority vectors.

$$W=\begin{cases} w_1=\frac{1}{3}\left(\frac{1}{1+8+4}+\frac{\frac{1}{8}}{\frac{1}{8}+1+5}+\frac{\frac{1}{4}}{\frac{1}{4}+\frac{1}{5}+1}\right)=8.9915\times10^{-2} \\ w_2=\frac{1}{3}\left(\frac{8}{1+8+4}+\frac{1}{\frac{1}{8}+1+5}+\frac{\frac{1}{5}}{\frac{1}{4}+\frac{1}{5}+1}\right)=0.30553 \\ w_3=\frac{1}{3}\left(\frac{4}{1+8+4}+\frac{5}{\frac{1}{8}+1+5}+\frac{1}{\frac{1}{4}+\frac{1}{5}+1}\right)=0.60456 \end{cases}$$

It is very easy to show that the eigen vector priority weights are $\begin{bmatrix} w_1^* \\ w_2^* \\ w_3^* \end{bmatrix} = \begin{bmatrix} 8.9915\times10^{-2} \\ 0.30553 \\ 0.60456 \end{bmatrix}$.

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

Belbao-Terol *et al.* (2014) argue that it is not realistic to distinguish sustainable or unsustainable countries based on quantitative data due to the conflicting aspects of each measure. They, however, continue to argue that when well-defined set of indices are aggregated and a methodology which can show joint performance of those indices is used, then so called a “good” country should be near the best score but far from the worst score, and a “bad” country should be close to the worst score but far from the best score. Adopting the scoring method for country data from Bilbao-Terol et al. (2014), TOPSIS is used in the later analysis to find a score for each country based on sustainability indices.

In 1981, Hwang and Yoon developed a Technique for Order Preferences by Similarity to Ideal Solution (TOPSIS). It is a technique for evaluating and ranking alternatives against several conflicting criteria for given representatives by choosing the best solution with the shortest distance from the positive-ideal solution but the farthest from the negative-ideal solution, and the worst solution with the shortest distance from the negative-ideal solution but the farthest from the positive-ideal solution. The algorithm of the TOPSIS is to evaluate the decision matrix or table with m rows and n columns and this thesis considers rows as country to country analysis and company in each country for corporate analysis and uses columns with the chosen SSCM indicators. To determine if the alternatives are located as close from the positive-ideal solution and as far from the negative-ideal solution at the same time, the analysis takes the weighted minimum

Euclidean distance. The methods described herein are the general steps of TOPSIS model adopted from Hwang and Yoon (1981, p 128-132):

Step 1. *Have a set of matrix for selected data:*

$$D = \begin{matrix} \\ a_1 \\ \vdots \\ a_i \\ \vdots \\ a_m \end{matrix} \begin{matrix} c_1 & \cdots & c_j & \cdots & c_n \\ \left[\begin{matrix} x_{11} & \cdots & x_{1j} & \cdots & x_{1n} \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ x_{i1} & \cdots & x_{ij} & \cdots & x_{in} \\ \vdots & \cdots & \vdots & \cdots & \vdots \\ x_{m1} & \cdots & x_{mj} & \cdots & x_{mn} \end{matrix}\right] \end{matrix}$$

where

a_i = *the* i^{th} *alternative considered,*

c_j = *the* j^{th} *criterion*

x_{ij} = *the numerical outcome of the* i^{th} *alternative with respect to the* j^{th} *criterion*

Step 2. *Normalize the decision Matrix by using*

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}$$

such that

$$D = \begin{bmatrix} \frac{x_{11}}{\sqrt{\sum_{i=1}^{m} x_{i1}^2}} & \cdots & \frac{x_{1j}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} & \cdots & \frac{x_{1n}}{\sqrt{\sum_{i=1}^{m} x_{in}^2}} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \frac{x_{i1}}{\sqrt{\sum_{i=1}^{m} x_{i1}^2}} & \cdots & \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} & \cdots & \frac{x_{in}}{\sqrt{\sum_{i=1}^{m} x_{in}^2}} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \frac{x_{m1}}{\sqrt{\sum_{i=1}^{m} x_{i1}^2}} & \cdots & \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} & \cdots & \frac{x_{mn}}{\sqrt{\sum_{i=1}^{m} x_{in}^2}} \end{bmatrix}$$

where

r_{ij} *= normalized decision matrix element*

Step 3. *Construct the weighted normalized decision matrix by multiplying weights for each criteria:*

$$V = \begin{bmatrix} w_1 r_{11} & \cdots & w_j r_{1j} & \cdots & w_n r_{1n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ w_1 r_{i1} & \cdots & w_j r_{ij} & \cdots & w_n r_{in} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ w_1 r_{m1} & \cdots & w_j r_{mj} & \cdots & w_n r_{mn} \end{bmatrix} = \begin{bmatrix} v_{11} & \cdots & v_{1j} & \cdots & v_{1n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ v_{i1} & \cdots & v_{ij} & \cdots & v_{in} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ v_{m1} & \cdots & v_{mj} & \cdots & v_{mn} \end{bmatrix}$$

where

w_j *= weight associated with* c_j

v_{ij} *= weighted normalized decision matrix element*

Step 4. *Determine positive-ideal and negative-ideal solutions by letting the two artificial alternatives* A^+ *and* A^- *defined as*

$$A^{+} = \left\{ \left(\max_i v_{ij} \mid j \in J \right), \left(\min_i v_{ij} \mid j \in J' \right) \mid i = 1, 2, \ldots, m \right\}$$
$$= \left\{ v_1^{+}, v_2^{+}, \ldots, v_j^{+}, \ldots, v_n^{+} \right\}$$

$$A^{-} = \left\{ \left(\min_i v_{ij} \mid j \in J \right), \left(\max_i v_{ij} \mid j \in J' \right) \mid i = 1, 2, \ldots, m \right\}$$
$$= \left\{ v_1^{-}, v_2^{-}, \ldots, v_j^{-}, \ldots, v_n^{-} \right\}$$

where

$J = \left(j = 1, 2, \ldots, n \mid j \text{ is a benefit related criteria} \right)$

$J' = \left(j = 1, 2, \ldots, n \mid j \text{ is a cost related criteria} \right)$

Step 5. *Calculate the separation measures between each alternative and positive-ideal and negative-ideal solution by the n-dimensional Euclidean distance:*

$$S_i^{+} = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^{+} \right)^2}, \qquad i = 1, 2, \ldots, m$$

$$S_i^{-} = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^{-} \right)^2}, \qquad i = 1, 2, \ldots, m$$

Step 6. *Calculate the relative closeness to the positive-deal and negative-ideal solution:*

$$C_i^{+} = \frac{S_i^{-}}{\left(S_i^{+} + S_i^{-} \right)}, \quad 0 < C_i < 1, \quad i = 1, 2, \ldots, m$$

Note that if $v_i = A^{+}$ *then* $C_i = 1$ *and if* $v_i = A^{-}$ *then* $C_i = 1$*, in other words, the alternative* a_i *is closer to the positive-ideal solution,* A^{+}*, as* C_i^{+} *approaches to 1.*

Step 7. *Rank the preference order according to the descending order of* C_i^{+}*.*

The benefit of using TOPSIS is that each criterion does not need to have same units as the units do not disturb measuring distance.

Yoon and Hwang (1995) presents following example (pg. 39-46):

Graduate Fellow Selection Decision: A sociology department want to select a student to receive a fellowship award from among applicants to its graduate program. The selection criteria of the department are GRE, GPA, college rating, recommendation rating, and faculty interview rating. Table A shows the evaluation of six applicants based on these attributes. The GRE score is on an 800-point scale, GPA on a 4.0 scale, and the three ratings are on a 10-point scale where 10 is the best. Suppose the department sets the importance weights for the five attributes as (0.3, 0.2, 0.2, 0.15, 0.15). Which of the candidates will receive the fellowship?

Applicants	*GRE*	*GPA*	*College Rating* (CR)	*Recommendation Rating* (RR)	*Interview Rating* (IR)
Alfred (A)	*690*	*3.1*	*9*	*7*	*4*
Beverly (B)	*590*	*3.9*	*7*	*6*	*10*
Calvin (C)	*600*	*3.6*	*8*	*8*	*7*
Diane (D)	*620*	*3.8*	*7*	*10*	*6*
Edward (E)	*700*	*2.8*	*10*	*4*	*6*
Fran (F)	*650*	*4.0*	*6*	*9*	*8*

Table A. Profiles of Graduate Fellowship Applicants

Step 1. Normalization. Since each attribute is measured on a different scale, an attribute normalization is required. The normalized rating are given below:

$$\begin{array}{c} \\ A \\ B \\ C \\ D \\ E \\ F \end{array} \begin{array}{c} \begin{array}{ccccc} GRE & GPA & CR & RR & IR \end{array} \\ \begin{bmatrix} 0.4381 & 0.3555 & 0.4623 & 0.3763 & 0.2306 \\ 0.3746 & 0.4472 & 0.3596 & 0.3226 & 0.5764 \\ 0.3809 & 0.4128 & 0.4109 & 0.4301 & 0.4035 \\ 0.3936 & 0.4357 & 0.3596 & 0.5376 & 0.3458 \\ 0.4444 & 0.3211 & 0.5137 & 0.2150 & 0.3458 \\ 0.4127 & 0.4587 & 0.3082 & 0.4838 & 0.4611 \end{bmatrix} \end{array}$$

where the first element r_{11} *was obtained from*

$$0.4381 = 690 / \sqrt{\left(690^2 + 590^2 + \cdots + 650^2\right)}.$$

Step 2. Weighted Normalization. The chosen weights of (0.3, 0.2, 0.2, 0.15, 0.15) are multiplied with each column of the normalized rating matrix:

$$\begin{array}{c} \\ A \\ B \\ C \\ D \\ E \\ F \end{array} \begin{array}{c} \begin{array}{ccccc} GRE & GPA & CR & RR & IR \end{array} \\ \begin{bmatrix} 0.4381 & 0.3555 & 0.4623 & 0.3763 & 0.2306 \\ 0.3746 & 0.4472 & 0.3596 & 0.3226 & 0.5764 \\ 0.3809 & 0.4128 & 0.4109 & 0.4301 & 0.4035 \\ 0.3936 & 0.4357 & 0.3596 & 0.5376 & 0.3458 \\ 0.4444 & 0.3211 & 0.5137 & 0.2150 & 0.3458 \\ 0.4127 & 0.4587 & 0.3082 & 0.4838 & 0.4611 \end{bmatrix} \end{array} \begin{bmatrix} 0.3 \\ 0.2 \\ 0.2 \\ 0.15 \\ 0.15 \end{bmatrix} =$$

$$\begin{array}{c} \\ A \\ B \\ C \\ D \\ E \\ F \end{array} \begin{array}{c} \begin{array}{ccccc} GRE & GPA & CR & RR & IR \end{array} \\ \begin{bmatrix} 0.1314 & 0.0711 & 0.0925 & 0.0564 & 0.0346^- \\ 0.1124^- & 0.0894 & 0.0719 & 0.0484 & 0.0865* \\ 0.1143 & 0.0826 & 0.0822 & 0.0645 & 0.0605 \\ 0.1181 & 0.0871 & 0.0719 & 0.0806* & 0.0519 \\ 0.1333* & 0.0642^- & 0.1027* & 0.0323^- & 0.0519 \\ 0.1238 & 0.0917* & 0.0616^- & 0.0726 & 0.0692 \end{bmatrix} \end{array}$$

where the first element v_{11} *was calculated as* $(0.1314 = 0.3 \times 0.4381)$.

Step 3. Positive-Ideal and Negative-Ideal Solutions. Since all the chosen attributes are of benefit (the higher, the more preference), the positive-ideal solution consists of the largest value of each column, which are denoted by the symbol "$*$" in Step 2. That is, A$*$ = (0.1333, 0.0917, 0.1027, 0.0806, 0.0865).

The collection of the smallest values of each column in Step 2, which are denoted by the symbol "-," makes the negative-ideal solution. That is, A- = (0.1124, 0.0642, 0.0616, 0.0323, 0.0346).

Step 4. Separation Measures. The separation measures from A$*$ are computed first:

$$S_A^* = \sqrt{\sum_{j=1}^{5}\left(v_{Aj} - v_j^*\right)^2} = \left[\left(0.1314 - 0.1333\right)^2 + \cdots + (0.0346 - 0.0865)^2\right]^{1/2} = 0.0617$$

Separation measures from A$*$ of all alternatives are

$$\left(S_A^*, S_B^*, S_C^*, S_D^*, S_E^*, S_F^*\right) = \left(0.0617, 0.0493, 0.0424, 0.0490, 0.0655, 0.0463\right)$$

The separation measures from A- are computed as

$$S_A^- = \sqrt{\sum_{j=1}^{5}\left(v_{Aj} - v_j^-\right)^2} = \left[\left(0.1314 - 0.1124\right)^2 + \cdots + (0.0346 - 0.0346)^2\right]^{1/2} = 0.0441$$

All separation measures from are

$$\left(S_A^-, S_B^-, S_C^-, S_D^-, S_E^-, S_F^-\right) = \left(0.0441, 0.0608, 0.0498, 0.0575, 0.0493, 0.0609\right)$$

Step 5. Similarities to Positive-Ideal Solution. The value of C_A^* *is calculated from*

$$C_A^* = S_A^- / \left(S_A^* + S_A^-\right) = 0.0441 / \left(0.0617 + 0.0441\right) = 0.4167$$

All similarities to the positive-ideal solution are

$$\left(C_A^*, C_B^*, C_C^*, C_D^*, C_E^*, C_F^*\right) = \left(0.4167, 0.5519, 0.5396, 0.5399, 0.4291, 0.5681\right)$$

Step 6. Preference Rank. Based on the descending order of C_i^**, the preference order is given as [F,B,D,C,E,A], which selects applicant F as the awardee of the fellowship.*

Applicants	**S***		**S$^-$**		**C***	
	Value	**Rank**	**Value**	**Rank**	**Value**	**Rank**
A	0.0617	5	0.0441	6	0.4167	6
B	0.0493	4	0.0608	2	0.5519	2
C	0.0424	1	0.0498	4	0.5396	4
D	0.0490	3	0.0575	3	0.5399	3
E	0.0655	6	0.0493	5	0.4291	5
F	0.0463	2	0.0609	1	0.5681	1

Table B. Three Sets of Preference Rankings

Three preference orders based on the positive-ideal (S^* *), negative-ideal (* S^- *), and TOPSIS (* S^* *) are contrasted in Table B. Applicant C is ranked first by* S^* *and fourth by* S^-*. Applicant F is ranked second by* S^* *and first by* S^-*. The selection of Applicant F by TOPSIS is equitable. The preference order by* C^* *happens to be identical with that of* S^-*.*

CHAPTER V. APPLICATIONS

This chapter covers two data analyses; one for country data and the other for an industry case study based on Heineken Company's annual sustainability report. Heineken Company is one of the largest beer companies that share not only the same rules and regulation but also sustainability goals to be achieved among manufacturers around the world. Country data are analyzed by using Microsoft Excel 2013, R (3.2.0), and R-Studio. Industry data are extracted from Heineken's 21 local sustainability reports and are displayed in tabular form by continents.

5.1 Applications to Country Data

As referenced above, all data for each Criterion, ANS, EF, EPI, HDI, LPI, and WGI are from publically available sources such as the World Bank, the Global Footprint Network, Yale University, and the United Nations. They are ranked by using TOPSIS with both equal weights and AHP weights. The rankings are call the Sustainability Performance Rankings (SPR)

5.1.1 Weight Criteria

In order to use TOPSIS method, relative weights of criteria are needed to calculate the weighted distance. The relative interest of each index can be easily changed depending on researcher's interest, but it needed be consistent. To provide priorities in hierarchial order, consistent weights are given to each criterion according to the 1 to 9 AHP scale developed by Saaty *at al.* (2012), as presented in Table 5.1.

Intensity of Importance	**Definition**	**Explanation**
1	Equal importance	Two activities contribute equally to the objective
2	Weak	
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favoured very strongly over another, its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If activity *i* has one of the above nonzero numbers assigned to it when compared with activity *j,* then *j* has the reciprocal value when compared with *i*	A reasonable assumption
Rationals	Ratios arising from the scale	If consistency were to be forced by obtaining *n* numerical values to span the matrix

Table 5.1 Saaty's fundamental scale (Saaty and Vargas, 2012. pg. 6)

The assumption is based on the preference and indifference relation. As shown in Table 5.2, it forms an 11 x 11 matrix instead of a 6 x 6 matrix as WGI contains six different sub-perspectives within criterion. This study considers EF, EPI, and HDI are equally important, so that;

$$EF = EPI = HDI$$

and the second most preference is given to LPI because this study focuses on supply chain management. As shown in the Table 5.2, as ANS and WGI are considered to be equally important, which means

$$ANS = WGI$$

In this analysis, EF, EPI, and HDI are considered to be strongly favoured over other criteria, ANS and WGI, by giving the scale of 5.

$$EF = EPI = HDI = 5ANS = 5LPI = 5WGI$$

As this study is focusing on supply chain management, LPI is considered as moderately favoured over ANS and WGI by giving scale 4, but still less favour than EF, EPI, and HDI.

$$LPI = 4ANS = 4WGI$$

Table 5.2 is a matrix based on above prefernces.

		ANS	EF	EPI	HDI	LPI	WGI					
							VA	PV	GE	RQ	RL	CC
ANS		1	0.2	0.2	0.2	.25	1	1	1	1	1	1
EF		5	1	1	1	5	5	5	5	5	5	5
EPI		5	1	1	1	5	5	5	5	5	5	5
HDI		5	1	1	1	5	5	5	5	5	5	5
LPI		4	0.2	0.2	0.2	1	4	4	4	4	4	4
WGI	VA	1	0.2	0.2	0.2	0.25	1	1	1	1	1	1
	PV	1	0.2	0.2	0.2	0.25	1	1	1	1	1	1
	GE	1	0.2	0.2	0.2	0.25	1	1	1	1	1	1
	RQ	1	0.2	0.2	0.2	0.25	1	1	1	1	1	1
	RL	1	0.2	0.2	0.2	0.25	1	1	1	1	1	1
	CC	1	0.2	0.2	0.2	0.25	1	1	1	1	1	1

Table 5.2 Pairwise Comparison Based on Saaty's Fundamental Scale

Table 5.2 is run in statistical software R (3.2.0) and R Studio in three different sets to and the set division is indicated with the bold line in Table 5.2. The first set is called TBL and include criteria adopted from Bilbao-Terol et al. (2014): ANS, EF, EPI, and HDI. The second set adds LPI to the first set and is called TBL LPI. Third set adds WGI to the second set and is called SSCMI. The AHP weighting result is presented in Table 5.3 along with the Saaty inconsistency.

	ANS	EF	EPI	HDI	LPI	WGI						Saaty's inconsistency
						VA	PV	GE	RQ	RL	CC	
TBL	0.0625	0.3125	0.3125	0.3125								-3.659401 E-16
TBL+LPI	0.0444	0.2928	0.2928	0.2928	0.0773							0.05802379
SSCMI	0.0374	0.2120	0.2120	0.2120	0.1024	0.0374	0.0374	0.0374	0.0374	0.0374	0.0374	0.02559308

Table 5.3 Weights by Using AHP

According to Saaty and Vergas (2012), an inconsistency of 10 percent (0.1) or less implies consistency. Because the Saaty's inconsistency for all three sets of data in Table 5.3 are much less than 10%, weighting scale are consistent and the matrix is accepted.

The Pearson correlation is used in Figure 5.1. If two indices are negatively correlated, which means they have an inverse relationship, then correlation value between them will result in between-1.0 and 0 (exclusively). If two indices are positively correlated, which means they increase or decrease together, then correlation value will result between 0 and +1.0 (exclusively). If two indices are independent of each other, the correlation will result in the value 0. On the other hand, if two indices are perfectly correlated, then the correlation value will result in either -1.0 or +1.0, for perfectly negative correlation and perfectly positive correlation, respectively. Based on Pearson correlation, there is high degree of positive correlation among the EPI, HDI, LPI, and sub-indices under WGI (VA, PA, GE, RQ, RL, and CC). This suggests that the countries with higher EPI value have more chance to focus more on human development, have better logistical performance, and have better governance. There is low degree of negative correlation between the

EF, EPI, HDI, sub-indices of WGI, respectively. The negative correlation means that the EF has conflicting sustainability data to EPI, HDI, and WGI, which suggest that the countries with higher human development and better governance tend to emit slightly more ecological footprint. It is easily detected that ANS has little relationship with other indices and also no indices are independent of other indices. Figure 5.1 also indicate the correlation coefficients among indices, and they indicate that each statistically significant relationship represent. Figure 5.1 also indicates statistical significance of correlations based on two-tailed t-test.

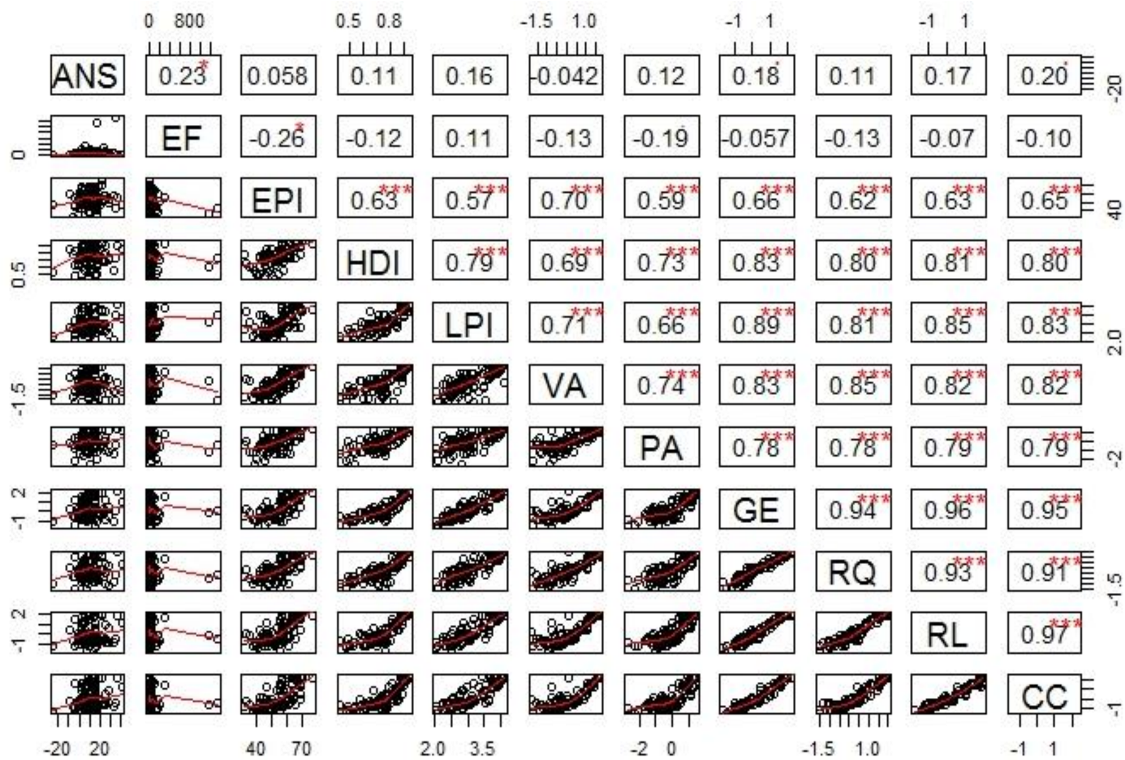

Figure 5.1 Scatter Plots and Pearson Correlation among Indices

* Pearson correlation coefficient is significant at the 0.05 level
** Pearson correlation coefficient is significant at the 0.01 level
*** Pearson correlation coefficient is significant at 0.001 level

5.2 Country Ranking by Using Equal Weight, AHP, and TOPSIS

Total of three sets of data is analyzed to find the most practical SSCM data set by adding LPI and WGI to basic TBL data accordingly. The first data set contains typical TBL criterion, adopted from Bilbao-Terol *et al.* (2014), including ANS, EF, EPI, and HDI, and they contain data from 95 countries. The second data set adds LPI to the first data, which turns out to be five countries less with 90 countries. The third data adds WGI to the second set, and the data size is same as the second set with 90 countries. Bangladesh, Israel, Mozambique, Nicaragua, and Zambia only exist in TBL data set. All data for applicable countries are from public databases. Data sets are named TBL, TBL+LPI, and SSCMI, respectively, for convenience and readability. Each data set are analyzed by using TOPSIS through a software R (3.2.0). The results are displayed in two different formats: tabular and world map adaped from (Wilson et al., 2007). Those two distinct format help to observe the differences among indices as well as the differences on same data with different weights. The tabular format is presented with countries, TOPSIS scores, and sustainability ranks, in alphabetical order of countries. The table is coloured for visualization. Top 20% sustainable country is coloured in dark green, the next 20% are coloured in light green, Third 20% are in yellow and forth 20% are in orange and the bottom 20% are in red. The map is represented the world map by ranking of countries, which are represented in different colours depending on their ranking. In this analysis, the ranking are compared to one with equal weights across criterion and the other with AHP weights. The SPR ranking with equal weights are presented in Table 5.4, and the SPR with AHP weights are shown in Table 5.5.

	TBL		TBL+LPI		SSCMI	
Country	**Score**	**Rank**	**Score**	**Rank**	**Score**	**Rank**
Albania	0.73054	72	0.72373	66	0.57301	56
Algeria	0.87928	5	0.86375	5	0.52572	69

Angola	0.59841	93	0.5909	88	0.45429	86
Argentina	0.73795	65	0.7322	59	0.56074	59
Armenia	0.72662	74	0.71891	71	0.58053	52
Australia	0.77564	39	0.77223	32	0.82862	10
Austria	0.79948	24	0.79664	21	0.83022	9
Azerbaijan	0.79878	25	0.78921	25	0.52012	73
Bangladesh	0.81519	15				
Belarus	0.8633	6	0.85189	8	0.53383	66
Belgium	0.76298	44	0.75984	40	0.7957	14
Bolivia	0.74986	53	0.74213	52	0.53697	65
Botswana	0.88297	4	0.87319	4	0.74794	20
Brazil	0.68904	88	0.68404	82	0.58593	48
Bulgaria	0.77476	40	0.7697	33	0.64297	34
Cameroon	0.71804	78	0.71037	73	0.4898	81
Canada	0.76282	45	0.75953	41	0.82214	12
Chile	0.68934	87	0.68381	83	0.73074	23
China	0.37292	94	0.37939	89	0.36938	89
Colombia	0.71338	80	0.70699	76	0.55135	62
Costa Rica	0.8094	16	0.80152	19	0.71704	28
Croatia	0.74155	60	0.7362	56	0.6628	32
Czech Republic	0.74013	63	0.73471	57	0.72062	27
Denmark	0.79449	27	0.79176	24	0.85073	6
Dominican Republic	0.70481	84	0.69782	79	0.55824	60
Ecuador	0.76007	47	0.75298	45	0.52493	70
Egypt, Arab Rep.	0.70866	82	0.70273	77	0.49521	79
El Salvador	0.74414	59	0.73644	55	0.59255	42
Estonia	0.80211	22	0.79509	22	0.77277	16
Ethiopia	0.74129	61	0.73156	60	0.48463	82
Finland	0.7654	42	0.76237	39	0.83785	7
France	0.76023	46	0.75704	42	0.77485	15
Georgia	0.75145	52	0.7445	50	0.62681	35
Germany	0.78342	34	0.7809	30	0.82079	13
Ghana	0.77599	37	0.76727	37	0.62668	36
Greece	0.67043	91	0.6639	87	0.60977	40
Guatemala	0.70863	83	0.70204	78	0.52209	72
Haiti	0.78857	32	0.77594	31	0.49013	80
Honduras	0.77587	38	0.76729	36	0.5375	64
India	0.32515	**95**	0.33008	**90**	0.3636	**90**
Indonesia	0.78847	33	0.78348	28	0.55388	61
Ireland	0.80535	19	0.8016	18	0.82705	11

Israel	0.79711	26				
Italy	0.7271	73	0.72317	69	0.6651	31
Jamaica	0.73804	64	0.72947	61	0.6071	41
Japan	0.71227	81	0.70903	75	0.75846	18
Jordan	0.74107	62	0.73319	58	0.58908	44
Kazakhstan	0.67748	90	0.67055	85	0.51001	76
Kenya	0.73172	68	0.72331	68	0.5104	75
Korea, Rep.	0.86178	7	0.85923	6	0.75146	19
Kyrgyz Republic	0.69318	86	0.68493	81	0.49927	78
Lebanon	0.73099	69	0.72331	67	0.51706	74
Macedonia, FYR	0.82711	13	0.81721	14	0.62223	37
Malaysia	0.80855	18	0.80476	15	0.67314	30
Mexico	0.75618	51	0.75068	46	0.58759	45
Moldova	0.77744	35	0.76748	34	0.5824	50
Mongolia	0.75705	50	0.74712	48	0.58631	46
Morocco	0.80036	23	0.79449	23	0.58136	51
Mozambique	0.72531	75				
Nepal	0.90683	3	0.88056	3	0.53081	68
Netherlands	0.80461	20	0.80204	17	0.85743	5
New Zealand	0.76743	41	0.76307	38	0.83477	8
Nicaragua	0.79207	28				
Nigeria	0.77634	36	0.76731	35	0.46623	85
Norway	0.85372	11	0.85086	9	0.89011	2
Pakistan	0.73254	66	0.72651	62	0.44619	87
Panama	0.85443	10	0.8468	11	0.64782	33
Paraguay	0.73235	67	0.72419	65	0.52484	71
Peru	0.79002	30	0.78362	27	0.58625	47
Philippines	0.85593	8	0.84919	10	0.57739	54
Poland	0.75913	48	0.75481	44	0.72638	24
Portugal	0.72396	76	0.71951	70	0.72453	26
Qatar	0.93667	2	0.92969	2	0.747	21
Romania	0.74475	58	0.73883	54	0.61525	39
Russian Federation	0.76404	43	0.7559	43	0.50955	77
Saudi Arabia	0.80303	21	0.79783	20	0.57469	55
Singapore	0.94419	**1**	0.94355	**1**	0.86419	4
South Africa	0.69368	85	0.68952	80	0.61551	38
Spain	0.74612	56	0.74241	51	0.72478	25
Sri Lanka	0.83272	12	0.82416	12	0.58488	49
Sudan	0.68531	89	0.67607	84	0.41709	88
Sweden	0.82667	14	0.82407	13	0.87757	3

Switzerland	0.85569	9	0.85327	7	0.89275	**1**
Tajikistan	0.75862	49	0.74889	47	0.48039	83
Tanzania	0.78942	31	0.78138	29	0.56307	58
Thailand	0.79014	29	0.78506	26	0.57781	53
Tunisia	0.71456	79	0.70919	74	0.56612	57
Turkey	0.74935	54	0.74535	49	0.5923	43
Ukraine	0.73087	71	0.72436	64	0.53321	67
United Kingdom	0.71969	77	0.71611	72	0.76985	17
United States	0.66577	92	0.66398	86	0.73866	22
Uruguay	0.73091	70	0.7249	63	0.69886	29
Venezuela, RB	0.74813	55	0.73968	53	0.46728	84
Vietnam	0.80921	17	0.80314	16	0.55117	63
Zambia	0.74486	57				

Table 5.4 Country Rank Using Equal Weights and TOPSIS

	TBL		TBL+LPI		SSCMI	
Country	**Score**	**Rank**	**Score**	**Rank**	Score	Rank
Albania	0.91566	33	0.92487	28	0.85548	39
Algeria	0.91432	35	0.91179	45	0.82372	69
Angola	0.85151	87	0.86477	82	0.79459	83
Argentina	0.90998	45	0.91779	38	0.84554	48
Armenia	0.89668	61	0.90244	57	0.8467	46
Australia	0.92448	22	0.93165	20	0.92562	12
Austria	0.94474	5	0.95403	4	0.9412	6
Azerbaijan	0.90225	51	0.90292	56	0.82375	68
Bangladesh	0.84035	88				
Belarus	0.93089	15	0.93003	22	0.83265	61
Belgium	0.92998	16	0.94007	12	0.92648	11
Bolivia	0.90509	48	0.91002	48	0.83566	59
Botswana	0.92423	23	0.92286	34	0.89328	25
Brazil	0.83563	90	0.84039	84	0.80658	77
Bulgaria	0.92043	28	0.92632	26	0.87452	33
Cameroon	0.87181	80	0.87545	77	0.80522	78
Canada	0.92179	27	0.93001	23	0.92408	13
Chile	0.90069	56	0.91263	44	0.89603	24
China	**0.1201**	**95**	**0.1009**	**90**	**0.1339**	**90**
Colombia	0.90355	50	0.91279	43	0.84389	50
Costa Rica	0.93986	7	0.94443	9	0.90144	20

Croatia	0.92337	25	0.93369	17	0.88652	29
Czech Republic	0.9252	21	0.9362	14	0.9037	18
Denmark	0.93898	8	0.94732	7	0.94201	5
Dominican Republic	0.89616	62	0.90443	55	0.84147	53
Ecuador	0.91729	29	0.92335	31	0.836	58
Egypt, Arab Rep.	0.88416	73	0.89113	67	0.81549	74
El Salvador	0.9013	53	0.9062	52	0.85068	41
Estonia	0.92859	17	0.9324	18	0.90995	17
Ethiopia	0.8664	83	0.86803	80	0.79703	82
Finland	0.93233	13	0.94275	10	0.93801	8
France	0.9222	26	0.93133	21	0.91431	15
Georgia	0.91418	36	0.92059	36	0.86923	34
Germany	0.91707	31	0.92329	32	0.91598	14
Ghana	0.89127	68	0.89272	66	0.85019	42
Greece	0.90094	55	0.91537	40	0.86713	35
Guatemala	0.89134	67	0.89861	62	0.82879	66
Haiti	0.87671	79	0.87579	76	0.79989	80
Honduras	0.90383	49	0.90637	51	0.83201	62
India	0.15202	94	0.1437	89	0.16991	89
Indonesia	0.81608	92	0.81575	87	0.77586	85
Ireland	0.9348	11	0.94054	11	0.9297	10
Israel	0.92666	18				
Italy	0.91488	34	0.92624	27	0.88325	30
Jamaica	0.90723	47	0.91314	42	0.85863	36
Japan	0.87923	77	0.88671	72	0.87793	31
Jordan	0.89199	66	0.89584	63	0.84571	47
Kazakhstan	0.86691	82	0.87332	78	0.81376	75
Kenya	0.88111	75	0.8846	73	0.81591	73
Korea, Rep.	0.9324	12	0.93407	16	0.9033	19
Kyrgyz Republic	0.8817	74	0.88828	71	0.8174	72
Lebanon	0.89881	58	0.90446	54	0.82925	65
Macedonia, FYR	0.91146	42	0.91134	47	0.85839	38
Malaysia	0.93163	14	0.93672	13	0.88664	28
Mexico	0.87865	78	0.88175	75	0.83316	60
Moldova	0.89748	59	0.89888	61	0.84174	52
Mongolia	0.89678	60	0.89934	60	0.8433	51
Morocco	0.89403	64	0.89509	65	0.8397	55
Mozambique	0.86759	81				
Nepal	0.91236	41	0.90825	49	0.82172	71
Netherlands	0.94294	6	0.95113	5	0.94569	4

New Zealand	0.93498	9	0.94529	8	0.93836	7
Nicaragua	0.91309	37				
Nigeria	0.8364	89	0.83562	85	0.76859	86
Norway	0.96022	2	0.96642	2	0.96028	2
Pakistan	0.8226	91	0.82348	86	0.75697	88
Panama	0.93484	10	0.9356	15	0.8759	32
Paraguay	0.90018	57	0.90578	53	0.83123	63
Peru	0.90888	46	0.91164	46	0.84988	43
Philippines	0.90117	54	0.9008	58	0.83608	57
Poland	0.92339	24	0.93211	19	0.90138	21
Portugal	0.91256	40	0.92303	33	0.89955	23
Qatar	0.92592	20	0.92371	30	0.89131	26
Romania	0.90223	52	0.90785	50	0.85862	37
Russian Federation	0.8595	86	0.86053	83	0.79706	81
Saudi Arabia	0.91617	32	0.91908	37	0.84766	44
Singapore	0.94863	4	0.94773	6	0.93438	9
South Africa	0.86246	85	0.86794	81	0.83699	56
Spain	0.91709	30	0.92632	25	0.89957	22
Sri Lanka	0.926	19	0.92704	24	0.85401	40
Sudan	0.86413	84	0.86896	79	0.77635	84
Sweden	0.95185	3	0.9595	3	0.9548	3
Switzerland	**0.9639**	**1**	**0.9712**	**1**	**0.9647**	**1**
Tajikistan	0.88101	76	0.88224	74	0.80357	79
Tanzania	0.88855	70	0.88949	68	0.82981	64
Thailand	0.91023	44	0.91398	41	0.84765	45
Tunisia	0.89222	65	0.89942	59	0.84403	49
Turkey	0.88521	72	0.88931	69	0.8414	54
Ukraine	0.89008	69	0.89522	64	0.82716	67
United Kingdom	0.9128	38	0.92479	29	0.91176	16
United States	0.76021	93	0.76268	88	0.76404	87
Uruguay	0.9127	39	0.92155	35	0.89	27
Venezuela, RB	0.91081	43	0.91645	39	0.81061	76
Vietnam	0.88845	71	0.88917	70	0.82241	70
Zambia	0.89521	63				

Table 5.5 Country Rank Using AHP and TOPSIS

In Table 5.4, Singapore has the highest score in both TBL and TBL+LPI. When WGI is added, however, Singapore drops to 4^{th} place and Switzerland scores 1^{st}. India scores the worst for all three data sets in Table 5.4. By using AHP weights, Switzerland scores the best and China scores the bottom for all three sets of data, as shown in Table 5.5. 20 countries as shown in Table 5.4, have the same colour throughout three sets of data, which means they are consistent in their ranking. In Table 5.5, however, 46 countries are detected to have same colour throughout three sets of data, which are double the number of Table 5.4. Number of countries such as Angola, Cameroon, China, India, Kazakhstan, and Sudan are observed to have the worst scores for both equal weighted and AHP weighted data. On the other hand, countries including Ireland, Norway, Singapore, Sweden, and Switzerland are observed to have the best scores for both equal and AHP weighted data. In Table 5.4, 11 extreme cases are found. This study determined extreme cases if the ranking range changed more than two colours. Under the condition that all indices are weighted equally, countries such as Japan, the United Kingdom, and the United States have one of the worst scores for TBL and TBL+LPI dataset, but they become one of the best-scored countries when WGI is added. Moreover, those countries Algeria, Azerbaijan, Belarus, Haiti, Honduras, and Nigeria have high scores in both TBL and TBL+LPI datasets, but when WGI is added, the score becomes one of the worst ones. It is interesting that AHP weighted data sets have only three extreme cases, which is far less than equal weighted data sets. Two different extreme case above, the countries including Japan, the United Kingdom, and the United States are so called highly developed countries and on the other hand, Algeria, Azerbaijan, Belarus, Haiti, Honduras, and Nigeria are so-called developing countries. It is interesting to observe that adding of WGI makes such big difference on SPR.

5.3 Data Mapping

Each data set are then represented in the coloured map by using R (3.2.0). Figure 5.2, 5.3, and 5.4 represent world map of TBL, TBL+LPI, and SSCMI, respectively, are measured with equal weights and Figure 5.5, 5.6, and 5.7 represent world map of TBL, TBL+LPI, and SSCMI, respectively, are measured by using weights calculated by AHP. According to Wilson et al., (2007), the benefit of such map is it provides a unique perspective of sustainable and unsustainable areas of the world. They also argue the maps will appear more similar to more consistent results. The same colour scheme as in tabular form is used as below;

1. top 20%, marked as 1 in legend, in dark green, followed by
2. light green
3. yellow
4. orange
5. and bottom 20%, marked as 5 in legend, in red

This mapping idea is adopted by Wilson et al. (2007), and he comes up with quantiles, which represent one being the top 20% quintile and five being bottom 20% quintile. He continues that the metrics in coloured map format offer a clear visualization of relative sustainable and unsustainable countries around the globe.

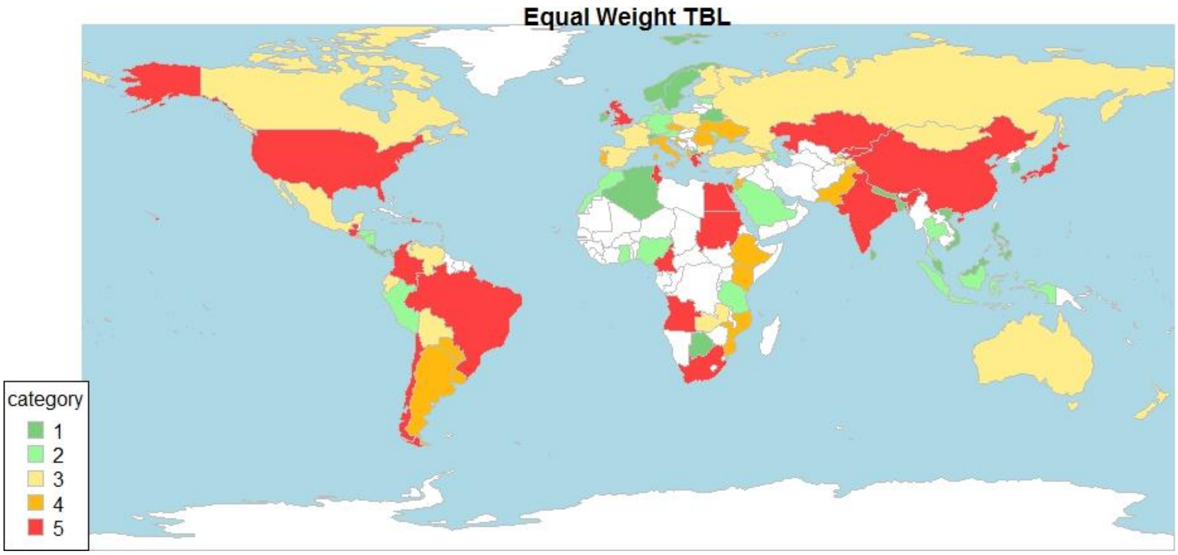

Figure 5.2 Equal Weights TBL

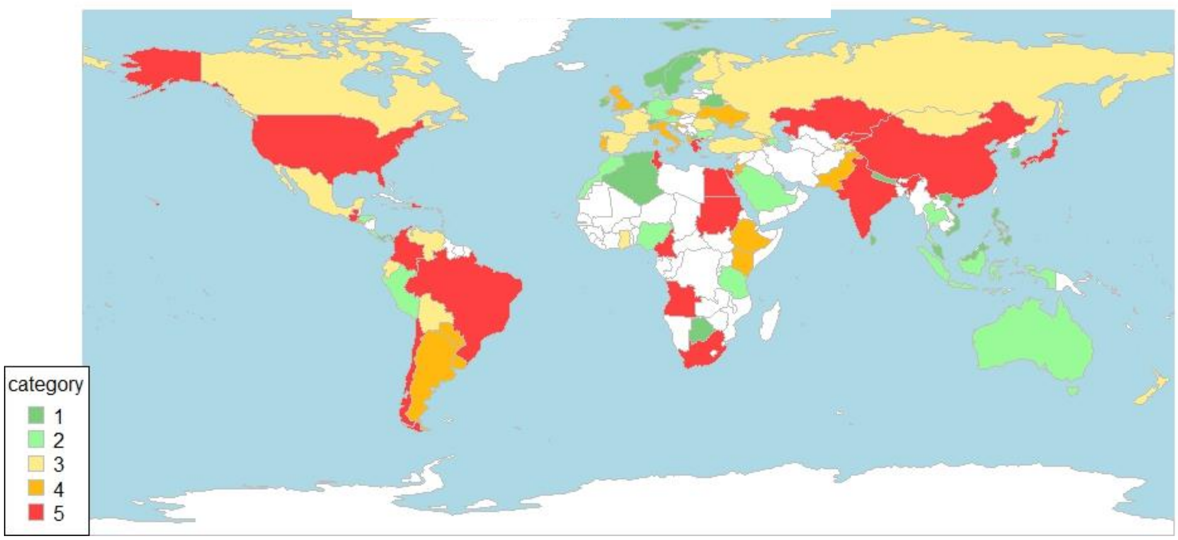

Figure 5.3 Equal Weights TBL+LPI

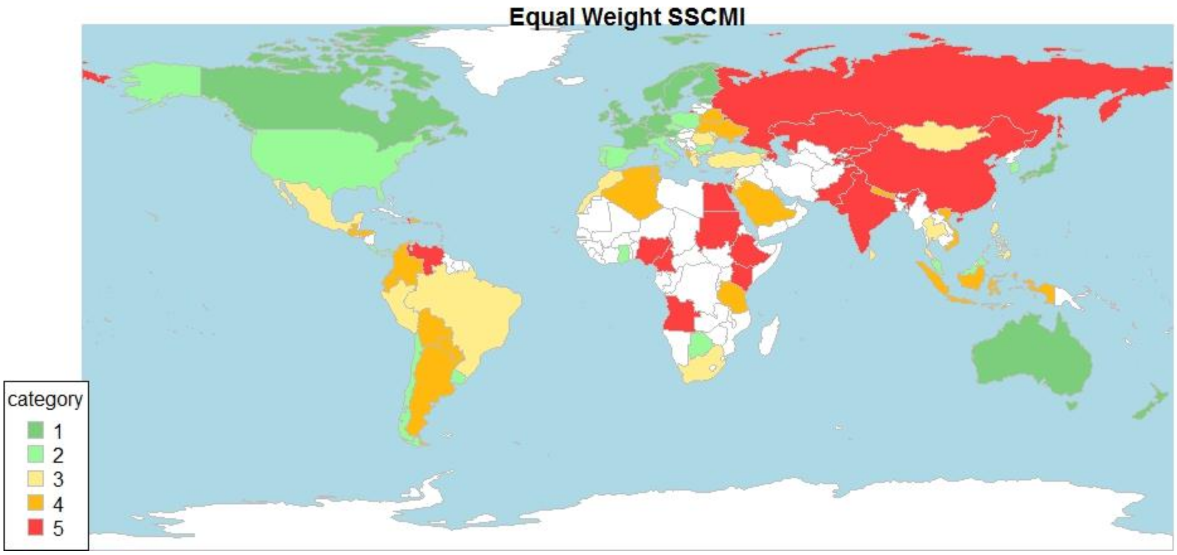

Figure 5.4. Equal Weights SSCMI

The Figures 5.2, 5.3, and 5.4 visually illustrate relative ranking by data sets. Figure 5.2 and 5.3 show similar patterns such that East Asia, including China, Japan, and India, and the United States are ranked in bottom for both maps. New Zealand, few European countries and few African countries seems to be ranked higher than other regions. Figure 5.4 is distinguished from previous maps as Russia appears to be ranked at bottom and Japan is ranked to be at top 20%. The United States, as well as Canada and many European countries, are ranked higher in sustainability with additional WGI indices.

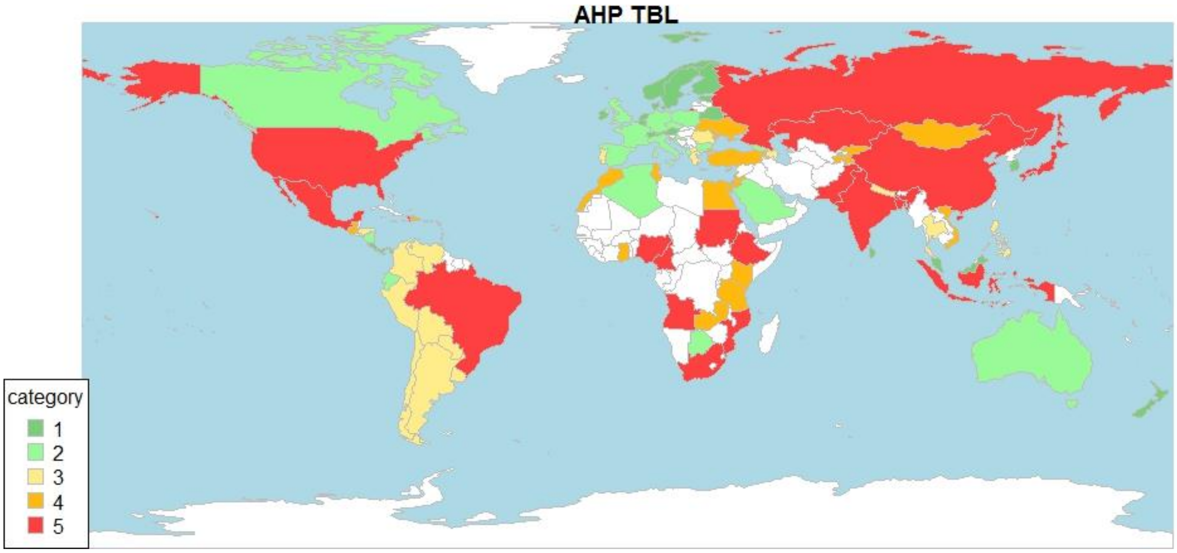

Figure 5.5 AHP TBL

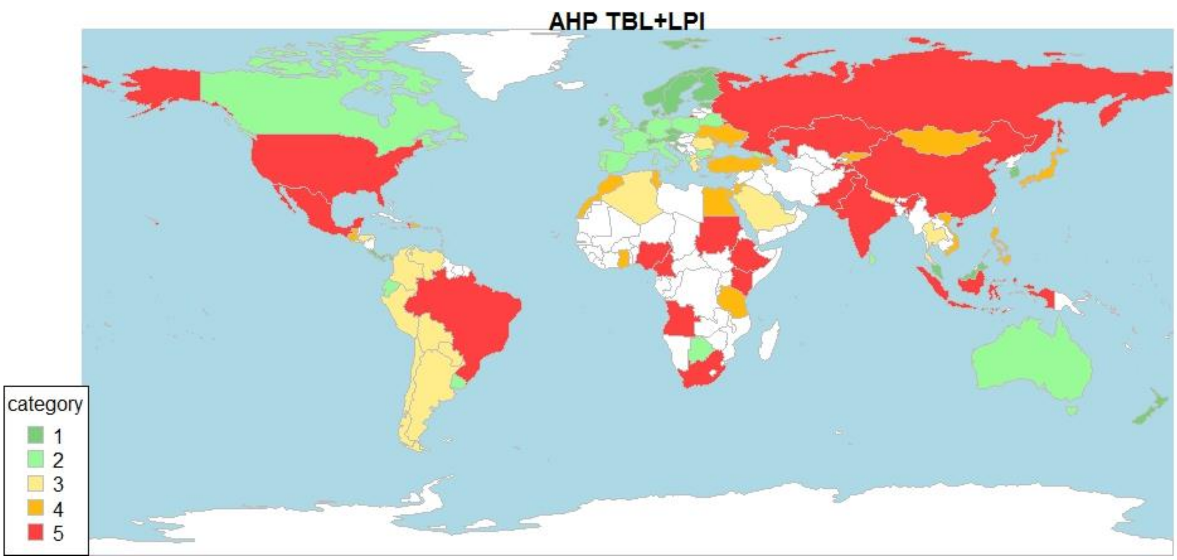

Figure 5.6 AHP TBL+LPI

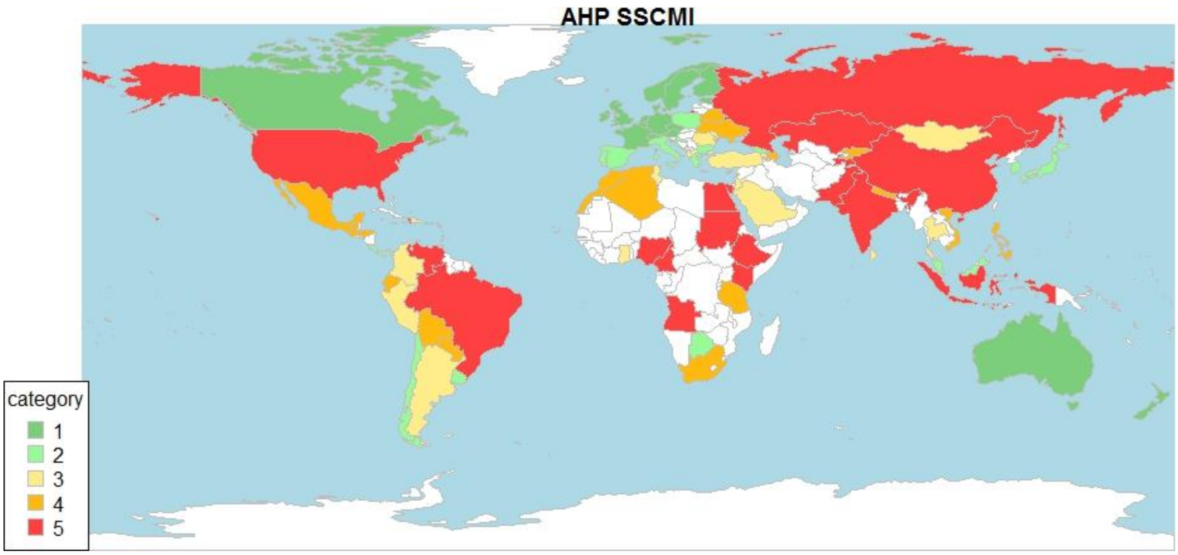

Figure 5.7 AHP SSCMI

The AHP weighted data maps in Figure 5.5, 5.6, and 5.7 are observed to be more consistent with its results than the equal weighted data set with consistent colour in a certain areas such as large, red coloured countries; Russia, China, and India. It is easy to detect that the AHP weighted maps look more consistent with similar colours thoughout than tha equal weighted maps.

5.4 Applications to Company Data

According to Labuschagne, Brent, and Van Erck (2005), there has been increased the pressure of sustainability performance onto industry stakeholders beyond their global economic performance. They argue that even with the increased pressure to pursuit sustainability, the idea of sustainability has not defined firmly in internal and external operational terms. They also say that there has been far less study has been done on industry level than those commonly accepted dimensions international, national, regional, or community-level sustainability. This thesis adds to this argument that there have been fewer efforts making the connection between national and industry level sustainability performance. In this dynamic and complex global world, number of local companies are connected to suppliers and buyers on the other side of the world. Would sustainable local business mean they are sustainable for their whole supply chain including their far-tiered suppliers in other countries than where the company reside in? This thesis observed sustainability of one of the world's largest beer companies, Heineken, who shares same goal throughout their manufacturers located in many different countries of the globe. Based on Heineken's sustainability reports, which is published every year by almost all manufacturers of Heineken around the world, this thesis tries to investigate the similarities or the difference of the sustainable supply chain management ranking between country and industry within the country as well as strengths and weaknesses of sustainability reporting of each country. The Global Reporting Initiative (GRI) is one of the organizations, which Heineken reports their sustainability reports to, every year.

5.4.1 The Global Reporting Initiative (GRI)

In this study, the Global Reporting Initiative, GRI, has been used collecting industrial sustainability data. According to GRI's website, it was founded in 1997 in Boston, the United States with the involvement of the United Nations Environment Programme (UNEP) and the Coalition for Environmentally Responsible Economies (CERES), one of the NGOs of the United States. It is one of the leading organization in the sustainable field, which provides a comprehensive sustainability reporting framework and promotes the use of sustainability reporting since 2000. All of GRI's sustainability reporting is publically available at free of charge. The database is user-friendly with filter and search function such as search by region or sector. GRI's sustainability report is about the economic, environmental, and social impacts caused by company or organization's routine activities and is published by the company or the organization themselves. The report should also include the organization's value and governance model as well as demonstrate the link between its strategy and the commitment to a sustainable global economy. It argues to publish the sustainable reporting, the organization would monitor its sustainability performance on ongoing basis and it, in fact, would not only improve its long-term profitability with ethical behaviour, social justice, and environmental care but also would help decision makers to shape their strategy and policies and also improve performance. The advantage of using data retrieved from GRI in this study is that it is publically available at free of charge. There also is increasing the number of sustainability reports adopting GRI guidelines throughout organizations around the world. GRI is used at global and national level and it referenced in the Plan of Implementation of the United Nations World Summit on Sustainable Development in 2002, and several governments, including Norway, the Netherlands, Sweden, and Germany considers GRI as sustainable development policy framework. According to Quaak, Aalbers, and Goedee (2007), the GRI aims to give tools to report sustainability measures, which in turn can compare the result with competitors to improve organization's management strategies.

5.4.2 The Heineken Company

The Netherlands-based beer company, Heineken, has been chosen an industry model who owns brewery in Europe, the Americas, Africa, the Middle East and Asia Pacific. It is world-recognized and the Europe's largest brewer, whom adjust its marketing to suit the tastes and needs of local markets, including more than 250 international premium, regional, local, and specialty beers as well as ciders according to Burns (2013) and Market Line (2013). It launched a long-term sustainability approach for both of its business and the stakeholders called a ‘Brewing a Better World’ in 2010. It has six key focused areas; protecting water resources, reducing CO_2 emissions, sourcing sustainably, advocating responsible consumption, promoting health and safety, and growing with communities. It considers own value chain as ‘from barley to bar’, including agriculture, malting, brewing, packaging, distribution, customer, and consumer. With Global Heineken sustainability goal so called ‘2020 ambition’, it not only publishes global sustainability report every year, but also publishes approximately 36 local sustainability reports every year from most of its brewery in different countries. The four common goals with detailed plan that Heineken shares across the world are presented in Table 5.7. They made commitment statement for four separate sections: protecting water resources, reducing CO_2 emissions, sourcing sustainability, and advocating responsible consumption. According to Quaak, Aalbers, & Goedee (2007), sustainability reporting is one of the many different ways for organizations to be transparent, which covers all aspects of a company’s Corporate Social Responsibility (CSR), and there are guidelines such as the GRI, which are used worldwide by organizations. Under the sustainability reporting, Heineken has three-year milestones, which allows both the company and stakeholders to monitor the progression and achievements to sustainability goals of 2020 ambition. The Heineken claims that the sustainability has been fundamental to its company since the business began, and it lies at the heart of everything they do. Its idea of sustainability as a company imperative means that “we act now to mitigate the impact of environmental and social risks and that we look at ways to create genuine economic opportunities for both our business and our stakeholders”, which the businesses in current society should retain to their value. Considered stakeholders not only include own investors, but also include employees, employee representatives, governments, industry associations, NGOs, international organizations, suppliers, and customers and consumers.

This study uses sustainability reports of Heineken based on 2012 to match the results with country analysis. An interesting analysis conducted by Market Line (2013) came across looking over the overall picture of Heineken's 2012 trend. In 2012, Heineken employed about 76,191 people on an average (Market Line, 2013). Market Line (2013) reports that the company's recorded revenue is approximately 23,636.9 million U. S. dollars in 2012 financial year with an increase of 7.4% over the 2011 financial year. It also reports there was an increase of 66.6% of operating profit, which turned out to be approximately 4,745.9 million U. S. dollars, and the net profit reached at approximately 3,791.8 million U. S. dollars, which is almost double increase from 2011 financial year. Market Line (2013) conducted a SWOT (Strengths, weaknesses, opportunities, and threats) analysis on Heineken as there is a risk of company's sales volume and market share due to the growing consumer preference towards craft beer regardless of its current strong market position. As shown in Table 5.6, the 2x2 matrix is used for SWOT analysis, which are strengths, weaknesses, opportunities, and threats. The strengths and weaknesses are due to internal factors, and opportunities and threats are due to the external factors. It analyzed three strengths, first being a dominant market share built on the strong brand portfolio. It is the leading brewer catering different consumer groups with the broad range of beer brands depending on different consumer taste and preference in Europe, the Americas, Africa, the Middle East and Asia Pacific. The second strength that Market Line argues is having a large scale of brewery and distribution network. It says Heineken has more than 165 breweries located in over 70 countries. It has diversified management subsidiaries, which manage the production and distribution, includes the Netherlands, the United Kingdom, Belgium, Austria, France, Hungary, Ireland, Slovensko, Switzerland, the United States and others. It comments that this diversified network of breweries helped the supply chain efficiency. With short shelf life compared to other beverages, the closer-to-consumer breweries help supplying fresh beers with appropriate taste and composition as well as reduce transportation costs. The third strength of Heineken is a brand innovation to adjust with the changes in consumer tastes and preferences. With focused on continuous innovation since 2009, both local and global innovations were encouraged. For example, in 2011, Orion, Heineken's in-bar draught beer storage system, has been developed to deliver better quality draught beer and increased in sales in double digits across several markets including Slovakia, the Czech Republic and Spain (Market Line, 2013, pg. 6). As there always are pros and cons, if there are strengths, then there exists weaknesses as well. As in Table 5.6, because of Heineken's high dependency on the European market, the company is vulnerable to economic shock in the particular region. The sales volumes are reduced with high unemployment, low consumer confidence, and a higher VAT (Value added tax) rate. According to SWOT (the strength, weakness, opportunity and threat) analysis, Heineken's opportunity lies on Asia-Pacific and African alcoholic market. The beer consumption has been increased in the Asia-Pacific market with increased disposable income and improved lifestyles especially in countries as Cambodia, India, Mongolia, and Vietnam. Even with the lowest per capita beer consumption in Africa, seven liters per year, the alcohol market is expected to grow along with economic growth, growing population, improving political stability, and increasing middle-class (Market Line, 2013. Pg. 7). In contrast, the craft beer and private label beers threat this giant beer company with their popularity and lower price. Increased volume of counterfeit alcohol is also surfaced up as one of the threats.

Strengths	**Weaknesses**

Dominant market position built on strong brand portfolio Large scale of brewery and distribution network Brand innovation to adjust with the changes in consumer taste and preferences	High exposure to the Western European market
Opportunities	**Threats**
Focus on Asia-Pacific beer market Huge potential in African alcoholic market	Growing craft beer market Penetration of private label beers Booming trade of counterfeit alcohol

Table 5.6 Heineken SWOT Analysis (an Informa Business, Market Line, pg. 4)

Heineken N.V. is one of the leading sustainable companies in the world as briefly mentioned in this section's introduction. Lambooy (2011) conducted a research regarding sustainable water usage of 20 Dutch multinational corporations, and Heineken was one of them. The study found that the Heineken is one of a few companies with concrete targets for water usage and emissions into the water. It also found that the Heineken implemented supply chain management policies regarding the environment throughout their supply chain with three-year local targets that concentrate on water consumption, management and treatment. According to the paper, it not only focuses on the environment, but also takes the social responsibilities. The CSR is one of rising issues in organizations, especially when it comes to company sustainability. Quaak, Aalbers, & Goedee (2007) argues that the driving factors, both internal and external, of CSR and sustainability reporting are same. They conducted qualitative research by interviewing Dutch brewery CEO's and managers to determine their knowledge about CSR activities. As a result, the driving factors of larger breweries turned out to be management, employee, neighbourhood, government, NGOs, complexity, knowledge, and shareholders (pg. 302).

5.4.3 Heineken Sustainability Report

The Heineken Company publishes sustainability report every year from many different countries in almost all continents of the world. In Africa, Egypt, Ethiopia, Algeria, Lebanon, and Nigeria are reporting their sustainability report every year. In Eastern Europe, Austria, Belarus, Czech Republic, Romania, Russia, and Poland participate in the sustainability report. In Western Europe, where the headquarter of Heineken (Netherlands) is located, Belgium, Finland, Ireland, Netherlands, Spain, Italy, Portugal, Switzerland, United Kingdom, and France, total of ten countries are participating in reporting every year. Croatia, Greece, Mexico, Panama, and the United States in America reports as well. Heineken does not publish sustainability reporting in Asia Pacific countries yet as they are currently expanding their business to Asia Pacific region. According to Heineken's sustainability reports, there are globally shared sustainability goals to achieve by 2020 that all Heineken companies share around the world. Heineken realizes unprecedented global challenges such as population growth, climate change access to natural resources and food and water scarcity and reports in almost every sustainability reports. It not only reports its sustainability report to GRI, but also get high scores from DJSI (Dow Jones Sustainability Index) and FTSE4Good, participate in Investors CDP (Carbon Disclosure Project) and CDP Water Disclosure Global Survey. The company recognizes those challenges affects corporate both directly and indirectly, which threatens key resources as well as prompting national and international policy demands. With the recognition of fining issues, risks, and opportunities regarding sustainability, it set four areas of sustainability milestones to achieve by 2015 and their ambitions for 2020 that were set in 2010. Those help to secure the long-term business at the same time fulfilling the social and environmental obligations. Below explains the Heineken's 2020 ambitions including four insights; water, CO_2, sourcing, and responsible consumption.

	Global Commitments for 2020
Water	Reduce specific water consumption in the breweries by 25%
	Aim for water compensation/ balancing by production units in water scarce and distressed areas
CO_2	Reduce CO_2 emissions: - In production by 40% - Of our refrigerators by 50% - Of distribution by 20% in Europe and the Americas
Sourcing	Deliver 60% of raw materials in Africa via local sourcing
	Aim for at least 50% of our main raw materials from sustainable sources
	Ongoing compliance with our supplier code procedure
Responsible Consumption	Deliver on industry commitments
	Make responsible consumption aspirational through Heineken
	Every market in scope has and reports publicly on a measurable partnership aimed at addressing alcohol abuse

Table 5.7 Global Commitments of Heineken for 2020

(Heineken USA sustainability report 2012, page 16 and 17)

In general, the sustainability report of Heineken consists of overview of brewing a better future, improvements on the environmental impacts, empowerment of people and communities, impacts of the role of beer in society, and additional information, tables, and backgrounds of Heineken sustainability. The overall Heineken's global sustainability performance report is published annually by Heineken N. V., headquarter located in Amsterdam, the Netherlands.

5.4.4 Heineken Sustainability Report 2012

Heineken's 2012 sustainability reports are based on the 2012 performance and is published either at the end of 2012 or in 2013 for the full-year-performance record. It reports number of different goals to achieve by the end of 2012 and the achievements based on their set goals and is explained in detail in Table 5.8 (pg. 8 – 17, Heineken N. V. Global Corporate Relations, 2012). As in Table 5.8, Heineken has not only grand goal by 2020 but also has specific goals for each year and monitor the achievements of each goal annually. The goal consists of seven big pictures; environment, green commerce, engaging employees, Heineken cares, responsible consumption, partnerships for progress, and enablers. They do cover a number of sustainability issues including environment, internal and external social care. It is interesting to see that they already included governance into their scope in order to achieve sustainability. One of the most important reason that Heineken is chosen as case study model is that Heineken already takes supply chain into an account in their sustainability. From Table 5.8, it is easily observed that the most of the goals set for 2012 has been achieved by the end of 2012 and those that are not achieved or partially achieved are reasoned and explain in detail with its progress.

Sustainability	**Goals by 2012**	**Achievements in 2012**
Environment	Specific total energy consumption < 155 MJ/hl	Partly achieved. 157 MJ/hl
	Average greenhouse gas emission < 8.5 kg CO2-eq/hl for breweries in scope	Achieved. 8.4 kg CO2-eq/hl
	Energy-efficient brewery designed	Achieved
	Specific water consumption < 4.3 hl/hl	Achieved. 4.2 hl/hl

	Water footprint studies performed	Achieved
	First water neutrality pilot conducted	Not achieved
	Inventories the environmental performance for offices, warehouses and brewery buildings offices, including studies for improving energy and water efficiency	Achieved. New monitoring system that collects data on total energy and water consumption and waste of 29 offices and 65 warehouses. Pilot projects for LEED and BREEAM sustainable buildings
Green Commerce	Design and adopt a new packaging policy with agreed targets for carbon reduction	Partly achieved
	Starting 2010, all new purchased fridges to be based on green technology, if legally and technically possible	Partly achieved. In 2012, 93 percent of the 134,285 fridges that Heineken purchased had at least one of 'green' characteristics and 37.5 percent had all three
	15 percent energy reduction of fridges in cooling against index	Achieved. Target exceeded by 250 percent. The average reduction was 48 percent
	Distribution efficiency standard defined for owned and outsourced operations	Achieved
	Evaluation criteria for new product innovations introduced in all regions	Achieved
	Continuous roll-out of guidelines on Life Cycle Assessment and carbon footprint for cooling equipment to suppliers	Achieved

	Develop and execute a baseline carbon footprint model	Achieved. The carbon footprint model covering the whole value chain has been developed and continuously improved. Carbon footprint at 24 operating companies covering more than 90 percent of Heineken Group volume are calculated.
	Carbon reduction opportunities in distribution identified through footprint reviews for top 20 markets	Achieved. Not the target is 10 percent reduction by 2015
Engaging Employees	Accident frequency target for supply chain < 1.2 accidents/100FTEs	Achieved. 1.16
	Safety targets set for non-production related activities	Achieved.
	Training modules for employees in high and medium safety risk functions rolled out	Achieved. Five health and safety modules are available at Health & Safety e-learning academy, which are available to all employees at all locations
	Employees' & Human Rights Policy adopted, implemented and audited	Partly achieved. Policy approved by the Executive Board in December 2011 and effective as of 1 January 2012. Implementation via gap analysis, however, is on-going to determine the gap between policy and local practices. This should be finalized by the end of 2013.
	Integrity included in employee surveys and followed up	Achieved
	Day of Giving Programme and volunteering scheme implemented in ten Operating Companies	Achieved. Employee volunteering activities (Day of Giving) took place in 27 Operating Companies in 2012

Heineken Cares	Evaluate all local sourcing activities and set regional targets for 2015	Partly achieved. Baseline has been verified and targets agreed for Africa and the Middle East. For other regions barley and hop local sourcing have been baselined.
	Evaluate reporting and monitoring system for agriculture; define an action plan to improve compliance	Partly achieved. The action plan for improving compliance will be done in 2013
	Standards for sustainable agriculture are aligned with and verified by stakeholders	Achieved.
	All operations that do not meet our defined standard of healthcare to include improvement plans by 2012	Partly achieved.
	In 2010: double funding for the Heineken Africa Foundation to EUR 20 million	Achieved.
	Inventory of possible partnerships with NGOs in the area of Corporate Social Investment (CSI)	Not achieved. Work in progress
	Perform 12 Economic Impact Assessments	Achieved. Four assessments conducted in 2012, bringing the total reports to 12 since 2010. Reports completed in the Bahamas, Burundi, Croatia, Egypt, Mexico, Nigeria (2x), Poland, St. Lucia, Surinam, the UK and the USA

Responsible Consumption	Develop 'Enjoy Heineken Responsibly' (EHR) to include on-trade exclusion; further extend the online programme; application of EHR in Heineken communication materials and primary merchandise; Migrate EHR website to consumer website Heineken.com	Achieved
	Horeca Server Programme and Retail Programme developed and tested	Partly achieved.
	Develop and deliver a workshop to 100 percent commerce/marketing employees that supports our Rules on Responsible Commercial Communication (RCC)	Partly achieved. A Responsible Commercial Communication module now forms part of the Global Commerce University (GCU) course. 83 percent of all relevant personnel have been trained
Partnerships for Progress	At least 50 Heineken markets have a partnership with a third party to address alcohol abuse	Partly achieved. In 2011, we adjusted the number of markets in scope on basis of legality, culture and market situation. As a result, there are a maximum of 42 markets in scope. On these, at the end of 2012, 33 markets had partnership and the quality and impact of the partnerships have improved since 2011
	Criteria for successful partnerships developed and existing partnerships reviewed	Achieved. The partnership criteria is used annually to measure the quality and impact of Operating Companies partnerships
	Global Actions on Harmful Drinking projects have been implemented in key markets	Achieved. A self-regulation, developing programmes and capabilities to reduce drinking & driving, "Global Actions" project is reported and evaluated

	Industry/government partnership projects in Ireland and UK implemented and evaluated	Achieved. In Ireland, a review of MEAS/Drinkaware took place Heineken UK is a signatory to the UK Government's Responsibility Deal and is signed up to all of the Alcohol sector pledges and has also made additional company pledges. On an annual basis, Heineken UK reports publicly to government on progress
Enablers	Executive level governance model as of launch of Brewing a Better Future (April 2010)	Achieved. The executive level Steering Committee consists of five Executive committee members. Each market has a local Steering Committee reporting to the General Manager
	From 2010: every Operating company to have a three-year sustainability plan	Achieved. As of 2011, all Operating Companies have a plan
	Renewed Supplier Code based on new approach by mid-2010	Achieved. At the end of 2012, 528 of our global suppliers and more than 34,000 local suppliers had signed the Supplier Code
	In 2010, introduce incentives for all senior managers on sustainability target	Achieved. 80 percent of all senior managers had an incentive on sustainability

Table 5.8 Heineken International Goals and Achievements in 2012

There exist a number of sustainability reports published by most of Heineken manufacturers around the world. Before get into further details for each country, a table which presents general information such as financial and production information of international Heineken and continents as in Table 5.9. Total revenue are presented as Euros as the headquarter of Heineken is located in Amsterdam, the Netherlands in Europe. The Heineken company produced 183.2 Mhl (million hectoliter) beverages and earned total revenue of €18,383M with 76,191 employees worldwide. The Heineken Company divided the continents into five sections;

Western Europe, Central and Eastern Europe, Americas, Africa and the Middle East, and Asia-Pacific. Western Europe is the biggest market of Heineken with total revenue of €7,785M with a fewer amount of total beverage produced, 44.3 Mhl, than Central and Eastern Europe (47.3 Mhl) and Americas (53.1 Mhl). Americas as a whole earned €4,523M, financially scoring a second place, with the most total beverage volume produced 53.1Mhl. The total revenue of Africa and the Middle East (€3,280M) is similar to Central and Eastern Europe (€2,639M), which represent 14.40% and 17.80%, respectively. The total beverage volume produced in 2012, however, Central America is double than Africa and the Middle East with 47.3 Mhl and 23.3 Mhl, respectively. Heineken's Asia-Pacific market is yet small, but growing. It acquired beer volume growth by 6.2%, which came from countries such as Vietnam, Indonesia, South Korea, and India and revenue growth in Taiwan, Hong Kong, and Australia. This data, however, mush have some miscalculated value, especially the total revenue and total revenue % part. When total revenue for all five continents is summed up, it comes out to be € 18,754M, instead of € 18,383M. Also when the total revenue percentage for all five continents are summed up, it turns out to be 102% of revenue, which should turn out to be 100%.

Continent	**Total Revenue**	**Total Revenue %**	**Total beverage Produced (EN00)**	**Consolidated beer volume as % of Group**	**Total number of employees (LA1)**
World	**€18,383M**	**102.00%**	**183.2 Mhl**	**100.00%**	**76,191**
Western Europe	€7,785M	42.30%	44.3 Mhl	25.80%	18,463
Central and Eastern Europe	€3,280M	17.80%	47.3 Mhl	27.50%	16,835
Americas	€4,523M	24.60%	53.1 Mhl	30.90%	25,035

Africa and Middle East	€2,639M	14.40%	23.3 Mhl	13.60%	14,604
Asia Pacific	€527M	2.90%	3.7 Mhl	2.20%	1,254

Table 5.9 Heineken Overall Performance in 2012 by Continent
(Heineken Annual Report 2012)

The overall picture in Heineken international's report, as in Table 5.9, does not provide sustainability aspect of Heineken, except the financial aspect. Oppositely, most of the sustainability reports published by each manufacturer from each country does not provide any financial nor production volume information based on collected information, which are publically available. Thus, the TOPSIS analysis covering all countries is not able to conduct. In order to compare the sustainability results analyzed for countries to Heineken Company, the Heineken sustainability reports for each country are explored. This explorations include manufacturers reside in countries in SSCMI data for comparability. In other words, in Africa, La Reunion, Rwanda, Sierra Leone, Burundi, and Democratic Republic of Congo's sustainability reports are not considered. In Central and Eastern Europe, Hungary, Serbia, and Slovensko are excluded and so as Brasserie Lorraine – Martinique and Suriname in the Americas. All Western Europe countries, who reported sustainability reports in 2012, are included in this study as all of those countries are included in SSCMI dataset. As no country report for Asia-Pacific is available, Asia-Pacific report is disregarded in this thesis. Even though it was impossible to extract and present every single information from each country's sustainability reports in this thesis, the number of values under specific criterions are collected and presented in tabular format by continent. The information that can be numerically presentable is preferred for future empirical study. The order of Tables is as follows: Africa and Middle East (Table 5.10), Central and Eastern Europe (Table 5.11), Americas

(Table 5.12), and Western Europe (Table 5.13). Tables are coloured in different colours to relate each criterion with country indices. ANS is labeled with light lavender, EPI with green, EF with light green, HDI with pink, LPI with yellow, and WGI with blue.

It is observed that sustainability reports of Africa and the Middle East countries shares the similar format of reports among Egypt, Ethiopia, Algeria, Lebanon, and Consolidated Breweries Plc in Nigeria, except Nigerian Breweries Plc in Nigeria. Nigeria publishes two different sustainability report, one by Consolidated Breweries Plc. and the other by Nigerian Breweries Plc. African country reported five aspects of sustainability, EPI, EF, HDI, LPI, and WGI, except ANS. They, however, reported the less information than any other continents, again, except Nigerian Breweries Plc in Nigeria. All African countries in Table 5.10 managed to report total energy consumption, and total water consumption under EPI concept, total direct and indirect CO_2 emission under EF concept, total number of employees and accident frequency under HDI, and the promotion of responsible consumption. Nigerian Breweries Plc. are explained separately for convenience. Average of 276.4 MJ/hl of electrical energy and average of 7.1 hl/hl of water has been consumed in 2012. Among all, Nigeria Consolidated Breweries Plc. consumed the most electrical energy and water, 355.7 MJ/hl and 9.4 hl/hl. It also emitted the most greenhouse gases by emitting 28.2 kg CO_2/hl. Egypt managed to have the lowest accident frequency with 0.6 cases/100 FTE (Full-time equivalent) with the most number of employees, 1963, but Ethiopia has the fewest days of accident severity with 11 lost calendar days/100 FTE. Egypt, Algeria, and Nigeria Consolidated Breweries Plc replaced 100% of their new fridges into green-fridges, which have average energy saving of 38%, and 93% of replaced new fridges were green in Lebanon. Ethiopia did not report its green fridge rate. With the leading total waste recycling rate of 99.6% in Lebanon, Algeria scores the lowest waste recycling rate with 79.8%. Nigeria Consolidated

Breweries Plc. is one of the only manufacturers who reported the percentage of locally sourced raw and packaging materials. They reported that 71% of raw and packaging materials were sourced from Nigeria in 2012. All firms indicated that they promote responsible consumption in variety ways such as incorporating "Drink Responsibly" message on product packaging and advertisements. Nigerian Breweries Plc, the pioneer and the largest breweries in Nigeria, reported the most information in Africa. They not only reported indices that other African firms above reported, but also reported total revenue (252.7 Billion Nigerian Naira), total consumption of thermal energy (131.7 MJ/hl), number of employees trained on various sustainability issues (2513), reuse of packaging (80%), and number of employees trained on the company alcohol policy (2513). The sustainability report format of Nigerian Breweries Plc. looks different from those neighbouring African countries.

Country	**Total Revenue**	**Total consumption of thermal energy (EN03)**	**Total energy consumption (Electric) (EN04)**	**Total water consumption (EN08)**	**Total direct and indirect emissions of greenhouse gases (EN16)**	**Total number of employees (LA1)**
Egypt			226.4 MJ/hl	5.3hl/hl	12.9kg CO2/hl	1,963
Ethiopia			310.7 MJ/hl	8.7 hl/hl	16.5 kg CO2eq/hl	1,214
Algeria			243.7 MJ/hl	6.5 hl/hl	14.2 kg CO2/hl	405
Lebanon			245.5 MJ/hl	5.6 hl/hl	20.0 kg CO2/hl	206
Nigeria (Consolidated Breweries Plc)			355.7 MJ/hl	9.4 hl/hl	28.2 kg CO2/hl	1,628
Nigeria (Nigerian Breweries Plc)	N252.7 billion	121.7 MJ/hl	10.2 KWh/hl	5.6 hl/hl	16.6 kg CO2/hl	3,220
Country	**Accident frequency (cases/100 FTE)**	**Accident severity (lost calendar days/ 100 FTE)**	**Number of employees trained on various sustainability issues**	**Number of direct or indirect personnel participated in safety enhancement exercise**	**Green Fridge (probability)**	**Total waste recycling rate**

Egypt	0.6	20			100%	93.70%
Ethiopia	1.4	11				97%
Algeria	13.6	113			100%	79.80%
Lebanon	1.2	17			93%	99.60%
Nigeria (Consolidated Breweries Plc)	1.2	12			100%	92%
Nigeria (Nigerian Breweries Plc)	0.4		2,513	5,131	100%	

Country	**Reused packaging**	**Locally sourced raw and packaging materials or from sustainable source**	**Promotion of responsible consumption**	**Number of employees trained on the company alcohol policy**		
Egypt			yes			
Ethiopia			yes			
Algeria			yes			
Lebanon			yes			
Nigeria (Consolidated Breweries Plc)		71%	yes			
Nigeria (Nigerian Breweries Plc)	80%	58%	yes	2,513		

Table 5.10 Heineken Sustainability Report 2012 – Africa and Middle East

Austria, Belarus Czech Republic, Greece, Romania, Russia, and Poland are part of Central and Eastern European countries based on Heineken’s boundary. Sustainability reports for Belarus and Russia are available, but since both are reported in their own language, it was unable to extract information. Based on remaining six countries, Poland (17) and Czech Republic (13) has the most information, followed by, Greece (11), Romania (11), Austria (10), and Croatia (9). It is observed that Austria and Poland have a different style of the reporting format. All of them managed to provide information on total energy consumption and total water consumption, which are related to EPI, total direct and indirect greenhouse gas emissions under EF, accident severity for HDI, and promotion of responsible consumption for WGI. Poland is the only country which reports total revenue of 3,619.5M PLN and also total produced beverage of 11,505,339 hl. All six countries publish their sustainability reports in English, but they use different units for several indices. For total energy consumption, all countries except Austria reports with the same unit as above African countries, MJ/hl. Austria, on the other hand, reports with kWh/hl, so the average value is not found. Poland and Greece in other hand reports combined the total value of thermal and electric consumption, which is 1,313,715,021.87 MJ and 194.8 MJ/hl, respectively in 2012. Total water consumption values are reported in the same unit, hl/hl, except Poland, who reports value with m^3, 3,389,954 m^3. Greece emitted 14.1 kg CO_2/hl, where Poland emitted 2.15 kg CO_2/hl., which seems to be an extreme difference, but as Poland reports its yearly emission as 87,903,181 kg, the average value is not calculated. There is average of 51 calendar days/ 100 FTE of accident severity. Greece reports the longest of 69 calendar days/ 100 FTE, followed by Austria's 58 calendar days/ 100 FTE, Czech Republic's 44 calendar days/ 100 FTE, Poland's 43 calendar days/ 100 FTE, and Romania's 41 calendar days/ 100 FTE. Based on extracted information, Greece has the highest accident frequency and accident severity by recording 2.2 cases/100 FTE and 69 lost calendar days/ 100 FTE and Romania has the lowest accident frequency of 0.5 cases/ 100 FTE and accident severity of 41 lost calendar days/ 100 FTE among the other countries in Central and Eastern Europe based on given data. Austria and Poland reported the amount of industrial waste, co-products and packaging with 93,783 tons and 239,820 tons, respectively, which is a big difference. Czech Republic, Romania, and Poland reported non-recycled industrial waste by 0.30 kg/hl, 0.16 kg/hl, and 292.3 tons. As Poland reported in a different unit than other two countries, it is not proper to compare these three information. It is interesting to see that Austria produced 82.49 tons of hazardous waste where Poland produced 17.6 tons of it, which is opposite result from industrial waste, where Poland produced much more industrial waste, co-products and packaging. Romania claims to have more than 800 employees, where Greece 1000, Romania 1100, and Poland 4852 employees across the country. Czech Republic, Greece, and Romania claim that 100% of their new fridges are green-fridges and Poland claims that 75% of new fridges are green. Greece reports that 99.4% of their waste are recycled. Austria reported that they used 82% of their raw, and packaging materials are coming from local sources where the Czech Republic use 87%. the Czech Republic and Poland reported the number of signed supplier code they achieved, more than 1200 and 1400 of them respectively. Greece and Poland claim that 100% of their suppliers are signed on supplier code in 2012. Romania did not report the number of signed code but reported they have 'almost' 100% of signed supplier code, which is not an exact number. Promotion of responsible consumption is done by all five countries, and 80% of Czech Republic's and 100% of Greece's senior managers are with sustainability objective.

Country	**Total Revenue**	**Total beverage Produced (EN00)**	**Total consumption of thermal energy (EN03)**	**Total energy consumption (Electric) (EN04)**	**Total water consumption (EN08)**
Austria			61.9 MJ/ hl	6.8 kWh/hl	3.44 hl/hl
Croatia				168.5 MJ/hl	4.8 hl/hl
Czech Republic			76.6 MJ/hl	147 MJ/hl	3.8 hl/hl
Greece			194.8 MJ/hl		5.2 hl/hl
Romania			64.6 MJ/hl	127.3 MJ/hl	3.9 hl/hl
Poland	3,619.5M PLN	11,505,339hl	1,313,715,021.87 MJ		3,389,954 m3

Country	**Total direct and indirect emissions of greenhouse gases (EN16)**	**NOx emissions (EN20)**	**SOx emissions (EN20)**	**Industrial waste, co-products and packaging (EN22)**	**Industrial waste not recycled (EN22)**	**Hazardous waste**	**Total number of employees (LA1)**
Austria	3.51 kg CO2/hl			93,783 tons		82.49 tons	
Croatia	9.2 kg CO2/hl						359
Czech Republic	9.1 kg CO2/hl				0.30 kg/hl		800
Greece	14.1 kg CO2/hl						1,000
Romania	7.1 kg O2/hl				0.16 kg/hl		1,100

Poland	87,903,181 kg	52,741 kg	11,999 kg	239,820 tons	292.3 tons	17.6 tons	4,852

Country	Accident frequency (cases/100 FTE)	Accident severity (lost calendar days/ 100 FTE)	Training and development days	% of employees took work safety classes	Green Fridge	Total waste recycling rate
Austria	2.1	58				
Croatia	0.7	72			100%	
Czech Republic	1	44			100%	
Greece	2.2	69	5,163		100%	0.994
Romania	0.5	41			100%	
Poland		43	3,157.50	2,841	75%	

Country	Locally sourced raw and packaging materials or from sustainable source	Number of Signed supplier code	% of Signed supplier code	Promotion of responsible consumption	Senior managers with a sustainability objective
Austria	82%			yes	
Croatia	90%			yes	
Czech Republic	87%	1200+		yes	80%
Greece				yes	100%
Romania			almost 100%	yes	
Poland		1,400	100%	yes	

Table 5.11 Heineken Sustainability Report 2012 – Central and Eastern Europe

There are three countries representing Americas in this thesis; Mexico, Panama and the United States. In Americas, Mexico has a different style of sustainability report format, and other two countries have the same format. Based on extracted data, Mexico has the most information (16) followed by Panama (9), and the United States (5). The reason the United States has so few information is that it reports many things in their 2012 sustainability report, but most of their data is based on global Heineken information. Moreover, also most of reported data are reported with percentage value with no explanation of how good or bad last year's achievements were. All manage to inform three criterion; total water consumption, the total number of employees, and promotion of responsible consumption. With Mexico's different unit of reporting yearly water consumption, 12,373,515.1 m^3, the average value cannot be calculated. Panama reported they consumed 7.9 hl/hl and the United States 4.18 hl/hl of water on average. Mexico has the most employees, 16,918, followed by the United States 491, and Panama 338. As other countries in other continents, Mexico, Panama, and the United States are promoting responsible consumption in their own ways. Total production of beverage is reported only by Mexico, 31,068 khl in 2012. It can be seen that Mexico is, again, the only country which reports the NOx (135,631 kg), SOx (509,675 kg), and Ammonia emission (292,188 kg), amount of industrial waste, co-products and packaging (436,484 tons) and hazardous waste (199.20 tons), and a high percentage of locally sourced raw and packaging materials (97%).

Country	**Total beverage Produced (EN00)**	**Total consumption of thermal energy (EN03)**	**Total energy consumption (Electric) (EN04)**	**Total water consumption (EN08)**	**Total direct and indirect emissions of greenhouse gases (EN16)**	**NOx emissions (EN20)**	**SOx emissions (EN20)**
Mexico	31,068.6 khl	2,901,478 GJ	257,226 MWh	12,373,515.1 m3	277,046 tons	135,631 kg	509,675 kg
Panama		261.4 MJ/hl		7.9 hl/hl	15 kg CO2/hl		
USA				4.18 hl/hl			

Country	**Ammonia (EN20)**	**Industrial waste, co-products and packaging (EN22)**	**Hazardous waste**	**Total number of employees (LA1)**	**Accident frequency (cases/100 FTE)**	**Accident severity (lost calendar days/ 100 FTE)**	**Donations**
Mexico	292,188 kg	436,484 tons	199.20 tons	16,918	1.62	165	
Panama				338	5.4	37	
USA				491			$ 100,000 US

Country	Green Fridge	Total waste recycling rate	Locally sourced raw and packaging materials or from sustainable source	Promotion of responsible consumption
Mexico			97%	yes
Panama	100%	875%		yes
USA	93%			yes

Table 5.12 Heineken Sustainability Report 2012 – Americas

There are total of ten countries who report sustainability in Western Europe and all of them are included in country analysis; Belgium, Finland, Ireland, the Netherlands, Spain, Italy, Portugal, Switzerland, the United Kingdom, and France. However, as in 2012, Switzerland published its report in Italian, German, and French, France in French, and the Netherlands in Duch, it was not possible to extract data from them at the moment. So only remaining seven countries are dealt in this thesis. Among fellow Western European countries, the most information are extracted from Spain (20), followed by the United Kingdom (15), Finland (14), Belgium (12), Ireland (9) and Italy (9), and Portugal (8). The legitimate sustainability report for Spain was not found, but the GRI report for 2012 is used for extraction of data. All seven countries manage to report total energy consumption, total water consumption, total direct and indirect emissions of greenhouse gases and promotion of responsible consumption. Spain, however, presents data in yearly bases, unlike other countries who submit their data in average value based on hectoliter of beer. Even though the average consumption based on hectoliter can be easily calculated with the total beverage volume produced in Spain in 2012, this thesis do not calculate not to disturb the original data, but criteria with all values are compared with calculated approximated value. The first criterion that all countries manage to report is total energy consumption. Neglecting Spain, as it has a different unit than others, the average energy consumption turns out to be 151.72 MJ/hl. Average total water consumption, again except Spain, turns out to be 4.06 hl/hl, with the highest value from Belguim, six hl/hl and the lowest from Portugal, 2.7 hl/hl. Belgium, Finland, Ireland, Italy, Portugal, and the United Kingdom emitted 6.845 kg CO_2/hl in 2012. The United Kingdom emitted the most greenhouse gases, 8.87 kg CO_2/hl, with a little difference with Italy, 8.87 kg CO_2/hl, and Portugal emitted the fewest greenhouse gases with 5.0 kg CO_2/hl. All seven countries promote responsible consumption in their unique ways. Spain's sustainability report unique criteria with yearly data such as SOx emission (15,188.3 kg), Ammonia emission (5,040 kg), and final effluent discharges (2,836,178 m^3), which are related to EF. Those criteria related to HDI also are reported such as number of contract workers (24), percentage of full-time workers (99.6%), percentage of full-time employees with life insurance (95.2%), percentage of full-time employees with private health insurance (23.2%), percentage of full-time employees with pension plans (97.6%), and percentage of full-time employees with covered disability/invalidity (100%). The United Kingdom also have two uniquely defined criteria, including the percentage of locally sourced materials, especially barley (100%) and percentage of locally brewed beers (95%). Looking at the total beverage produced, Spain (9,812,220 hl) produced beverage almost 3.45 times more than Belgium did in 2012. The amount of industrial waste, co-products and packaging, non-recycled industrial waste, and hazardous waste produced in Spain, however, is extremely higher than those in Finland. For example, the amount of industrial waste, co-products and packaging in Spain (212,276,602 tons) is approximately 8,641 times more than in Finland (24,565 tons), industrial waste not recycled in Spain (1,166,230 tons) is approximately 17,670 times more than in Finland (66 tons), and the amount of hazardous waste is approximately 4,339 times more in Spain (40,051 tons) and in Finland (9.23 tons). Italy has lowest percentage (68%) of signed suppliers code among those who reported the criteria such as the United Kingdom (100%), Ireland (98%), Belgium (95%), Finland (85%). Spain and Portugal fail to report the criterion.

Country	Total beverage Produced (EN00)	Total consumption of thermal energy (EN03)	Total energy consumption (Electric) (EN04)	Total water consumption (EN08)	Total direct and indirect emissions of greenhouse gases (EN16)	NOx emissions (EN20)	SOx emissions (EN20)
Belgium	1,400,000 hl	108.3 MJ/hl	225.7 MJ/hl	6 hl/hl	6.6 kg CO2/hl		
Finland	2,842,600 hl	59.8 MJ/hl	161 MJ/hl	3.1 hl/hl	5.3 kg CO2/hl	12,100 kg	
Ireland			105.5 MJ/hl	3.1 hl/hl	5.6 kg CO2/hl		
Spain	9,812,220 hl	645,206,046.20	81,211,218 MJ	3,979,650 m3	52,215,230 kg CO2	15,897.5 kg	15,188.3 kg
Italy		72 MJ/hl	150.5 MJ/hl	5.7 hl/hl	8.87 kg CO2/hl		
Portugal			115 MJ/hl	2.7 hl//hl	5.0 kg CO2/hl		
United Kingdom		79.25 MJ/hl	152.6 MJ/hl	3.8 hl/hl	9.7 kg CO2/hl		

Country	Ammonia (EN20)	Total final effluent discharges	Industrial waste, co-products and packaging (EN22)	Industrial waste not recycled (EN22)	Hazardous waste	Total number of employees (LA1)	Contract workers (LA1)
Belgium						500	
Finland			24,565 tons	66 tons	9.23 tons		
Ireland							
Spain	5,040 kg	2,836,178 m3	212,276,602 tons	1,166,230 tons	40,051 tons	1,548	24
Italy				0.02 kg/hl		2,000	
Portugal						852	
United Kingdom				0.01 kg/hl		2,300	

Country	% Full-time workers (LA1)	% Full-time employees with life insurance	% Full-time employees with private health insurance	% Full-time employees with pension plans	% Full-time employees with covered disability/invalidity	Accident frequency (cases/100 FTE)	Accident severity (lost calendar days/ 100 FTE)
Belgium						1.3	13

Finland						3.7	197
Ireland						4.5	
Spain	99.6%	95.2%	23.2%	97.6%	100%		
Italy						0.4	
Portugal						0.9	129
United Kingdom						0.9	21

Country	**Donations**	**Volunteer hours**	**Green Fridge**	**Total waste recycling rate**	**Locally sourced raw materials (barley)**	**Locally brewed beers**	**Percentage of Signed supplier code**	**Promotion of responsible consumption**	**Senior managers with a sustainability objective**
Belgium	€ 90,000		100%				0.95	yes	
Finland	€ 1,000,000						0.85	yes	
Ireland		2,000 hrs	100%	99.8%			0.98	yes	
Spain								yes	
Italy			100%				0.68	yes	
Portugal	€ 151,000							yes	
United Kingdom			93%	99%	100%	95%	100%	yes	1

Table 5.13 Heineken Sustainability Report 2012 – Western Europe

A few interesting observations are done while extracting Heineken's sustainability report data. First, the majority of reports are published in English, but a few were published in their own language. Few countries including Russia, Netherlands, Switzerland, and France published their own language, and this prevented data extraction for translation accuracy reason. Second, there are certain trends in reporting style, especially among African countries. Four out of five countries seems to have an almost identical style of reports with few basic information. Third, none of the reports, except Nigerian report, reports profit nor their production volume of the year. Sustainability generally mean economic benefit, environmental protection and social justice. Many of Heineken Company's sustainability report, however, do not report the financial portion of the sustainability report. Rather, complex and massive financial report, which only accountants would understand, is available publically, but it does not specify financial information for each country. Fourth, not all country have the same style of reporting style.

The intention of this Heineken sustainability report data collection is to analyze the data using AHP and TOPSIS by matching relative indices used in the country analysis. However, as much of Heineken sustainability report are different from country to country; many information is either missing or reported in different unit, which prevents from data analyzation. Also, as some of the reports are only reported in their own language, the data is unable to be extracted. However, this thesis achieves to rank country data by using developed SSCMI indices and finds that the TOPSIS scores for TBL+LPI is higher for most of the countries, but the scores for SSCMI is close TBL+LPI scores. SSCMI data is more valuable to consider as it includes governance of each country. This thesis also finds that a company with same sustainability goals and guidance across its manufacturers in different countries, the sustainability reporting style is different and sometimes reports in a different unit. It seems that publishing sustainability report is to show stakeholders that they publish a sustainability report less of an operational review of previous year's performance.

CHAPTER VI. CONCLUSION AND FUTURE RESEARCH DIRECTION

This study observes and analyzes both country and company data. It draws both theoretical and practical implications by quantifying sustainability in supply chain management context. By closely relating publically available real-world country data and existing methods AHP and TOPSIS, it enhances understanding of decision making methods within discipline of supply chain management. This research contributes by setting a base to compare sustainable supply chain management in national level and corporate level. By using publicly available data, which anyone has access to, all stakeholders including policy makers, decision makers, and customers, can access data and used it for their needs, at no cost. As the indices used in this thesis is not absolute indices to measure the sustainability of countries or firms, different weights can be given as it is a subjective measure, but it needs to be verified with its consistency. A mixed AHP-TOPSIS is a practical method, which takes one step further from the simple scoring model by measuring distance to and from the positive ideal solution and distance to and from the negative ideal solution. User-friendly statistical software such as R (3.2.0) and R Studio makes both AHP and TOPSIS even practical for simpler and faster process of getting results.

The contribution of this thesis is that it develops an indicator to quantify sustainability within supply chain management. It also extends the works of Bilbao-Terol *et al.* (2014) and Wilson *et al.* (2007) by comparing different combinations of data using equal weights, AHP, TOPSIS, and AHP-TOPSIS model. By categorising company data based on country indices, future study can use imputation using missing data methods.

The limitation of this study is that there were only 2007 EF data available for country ranking due to public availability. The dataset would have been better with 2012 EF data, but it was quite costly at the time of research. Also when SSCMI data is constructed according to countries with fulfilled data, there were only 90 countries left out of 248 available data from beginning. For corporate sustainability, Heineken's sustainability report did not have established the format of reporting, which in turn, the data analysis on data would not make sense. Heineken had highly detailed and complex international financial report for 2012 year, but most of local sustainability report did not report financial information nor their production volume. Also, a few reports tended to report only increase or decrease of percentages, not informing previous year's data.

Future research direction is to use imputation for missing variables. Since there is no developed imputation method in sustainability within supply chain management context, there is possibility of developing an imputation method. And by using imputation, company sustainable supply chain management can be quantified and can be ranked. It will enable a research to compare the results of country's sustainable supply chain management and company sustainable supply chain management. By comparing those ranking, the decision makers will make thorough decision making whether to consider base country or company itself when they need to choose more sustainable suppliers to comply with domestic and international laws and regulations. Other methods of TOPSIS are to be used by using different normalization techniques.

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APPENDICIES

Scatter Plots and Pearson Correlation among Indices

```
› library(psych)
› library(PerformanceAnalytics)
› chart.Correlations(index2)
› panel.cor <- function(x, y, digits=2, prefix="", cex.cor)
{
+ usr <- par("usr"); on.exit(par(usr))
+ par(usr = c(0, 1, 0, 1))
+ r <- cor(x, y)
+ txt <- format(c(r, 0.123456789), digits=digits)[1]
+ txt <- paste(prefix, txt, sep="")
+ if(missing(cex.cor)) cex <- 0.8/strwidth(txt)
+ test <- cor.test(x,y)
+ # borrowed from printCoefmat
+ Signif <- symnum(test$p.value, corr = FALSE, na = FALSE,
+ cutpoints = c(0, 0.001, 0.01, 0.05, 0.1, 1),
+ symbols = c("***", "**", "*", ".", " "))
+ text(0.5, 0.5, txt,cex=1.3)
+ text(.8, .8, Signif, cex=cex, col=2)
}
› pairs(index2,lower.panel=panel.smooth,upper.panel=panel.cor)
```

AHP Weights

```
› # Import AHP SSCMI as ʹdataʹ
› attach(data)
› data2<-data[,-1]
```

› rownames(data2)<-data[,1]

› data2

› index<-data2

› index1<-index[-c(5:11),-c(5:11)]

› index1

› # Representing ANS, EF, EPI, HDI

› index2<-index[-c(6:11),-c(6:11)]

› index2

› # Representing ANS, EF, EPI, HDI, LPI

› index3<-index

› library(pmr)

› ahp(index1)

› ahp(index2)

› ahp(index3)

TOPSIS on Country Data

› attach(index)

› index<-subset(index,select=-Country.Code)

› index2<-index[,-1]

› rownames(index2)<-index[,1]

› library(topsis)

› d<-as.matrix(index2)

› # for equal weights

› w<-c(1,1,1,1)

› i<-c(“+”, “-”, “+”, “+)

› t<-topsis(d,w,i)

› t<-data.frame(t,row.names= Country.Name)

- # to copy results into excel/csv format
- con=file(“clipboard”,open=“w”)
- write.table(t,file=con,sep=“\t”,col.names=TRUE)
- close(con)

Data Mapping – World Map

- install.packages("rworldmap")
- library(rworldmap)
- sPDF <- joinCountryData2Map(index, joinCode = "ISO3", nameJoinColumn ="CountryCode")
- par(mai=c(0,0,0.2,0),xaxs="i",yaxs="i")
- op<-palette(c('palegreen3','palegreen','lightgoldenrod1','darkgoldenrod1','brown1'))
- mapCountryData(sPDF,nameColumnToPlot='category',catMethod='categorical',mapTitle ='AHPSSCMI',colourPalette='palette',oceanCol='lightblue',missingCountryCol='white',addLegend=FALSE)