Evaluating and Enhancing the Impact of Sustainability Reporting Tools (SRTs)

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EVALUATING AND ENHANCING THE IMPACT OF SUSTAINABILITY REPORTING TOOLS (SRTs)

by

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Abstract

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In evaluating the impact of SRTs, four investigations are conducted. First, the link between environmental, social and governance (ESG) and financial performance is analysed using univariate, multivariate and portfolio analysis. Data for the period 2008-2010 are used. Results show that there is a weak relationship between ESG and financial performance represented by a wide range of financial ratios and stock returns. The portfolio of ESG leaders does not outperform the ESG laggards. Although analysts' forecast error is found to be negatively correlated to ESG, this observation is not significant. Second, the behaviour (price movement, index trend and trading volume) of the FTSE4Good Australia Index and its constituents are examined using a Markov chain analysis. Based on the results obtained, these company stocks do not seem to demonstrate superior performance. Third, an examination of building SRTs reveals that: variation in criteria scores and weights need to be accounted for; there is no large difference in occupants' satisfaction levels between a sustainable building (ascertained by building SRTs) and a non-sustainable building; and criteria scores are inconsistent for buildings with similar sustainability awards. Fourth, the current state of sustainability reporting of publicly-listed Australian construction companies is investigated. Contrary to expectation, the state of sustainability reporting is found to be poor with high evidence of graph obfuscation. That is, there is a biased use of graphs to depict favourable criteria in sustainability reports. Corroborative evidence from all four investigations appears to suggest that the effectiveness of SRTs is questionable.

To enhance the impact of SRTs, this thesis presents an alternative multi-criteria framework to assess sustainability performance of companies and building/infrastructure projects based on second order moment thinking. This framework is designed to overcome existing limitations and encompasses six different elements: (i) Criteria selection; (ii) Quantitative measurement scales for the criteria; (iii) Characterising each criterion by measures of central tendency and dispersion; (iv) The distinction of additionality; (v) Criteria weighting; and (vi) Combining criteria to give an overall sustainability score characterised by a measure of central tendency and a measure of dispersion. A tree form classification model of companies' sustainability performance is proposed. This model is developed using a combination of agglomerative hierarchical clustering and classification and regression tree (CART) techniques. Extending this model, the link between different clusters of companies ('Leader', 'Average' and 'Laggard') and sustainability maturity levels is established. As well, the fuzzy-based approach is recommended as a way to measure project sustainability maturity levels.

While the nature of return–risk efficient portfolio frontier has been discussed at length in the literature, it has not been extended to incorporate the analysis of sustainability issues, as done in this thesis. Leveraging on a few concepts such as the centre of gravity (COG) and Euclidean distances, the superiority of portfolios is differentiated by accounting for both return–risk and ESG–variance. These tools adopted are original contributions to help enhance stakeholders' decision making process.

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PUBLICATIONS

The analysis and empirical work in this thesis have resulted in the following publications. The publication process has been valuable in obtaining feedback to improve the research design and validate the usefulness of the approaches recommended.

No.	Journal Publications	Chapter
1	**Siew, Y. J. R.**, Balatbat, M. C. A. and Carmichael, D. G. (2013), A Review of Building/Infrastructure Sustainability Reporting Tools (SRTs), *Smart and Sustainable Built Environment*, Vol. 2, No. 2, pp. 106–139. ***(Highly Commended Paper award 2013)***	Chapter 3
2	**Siew, Y. J. R.**, Balatbat, M. C. A. and Carmichael, D. G. (2013), The Relationship Between Sustainability Practices and Financial Performance of Construction Companies, *Smart and Sustainable Built Environment*, Vol. 2, No. 1, pp. 6–27.	Chapter 7
	Conference Publications	
3	**Siew, Y. J. R.**, Balatbat, M. C. A. and Carmichael, D. G. (2011), Impact of Environmental, Social and Governance (ESG) Disclosures on Firm Performance, *Dynamics of Investing Responsibly Research Forum*, University of Sydney, Sydney, 24–25 November 2011.	Chapter 4
4	Balatbat, M. C. A., **Siew, Y. J. R.** and Carmichael, D. G. (2012), The Value Relevance of ESG Disclosures in Assessing Company Performance, *Australian GRI Conference on Sustainability & Integrated Reporting*, Melbourne, Victoria, 26–28 March 2012.	
5	Balatbat, M. C. A., **Siew, Y. J. R.** and Carmichael, D. G. (2012), Influence of ESG Scores on Firm Performance: Australian Evidence, *35th Annual Congress of the European Accounting Association*, Ljubljana, Slovenia, 9–11 May 2012.	
6	**Siew, Y. J. R.**, Balatbat, M. C. A. and Carmichael, D. G. (2013), Investigating the Impact of ESG on Firm Performance: Australian Evidence, *ETH – PhD Academy on Sustainability and Technology 2013*, Swiss Institute of Technology (ETH), Zurich, Switzerland, 2–7 June 2013.	
7	**Siew, Y. J. R.**, Balatbat, M. C. A., Carmichael, D. G. (2011), Influence of ESG on the Financial Performance of Australian Companies, *Symposium on Accounting, Reporting and Assurance for a Sustainable Future: Risks and Opportunities*, Nanyang Technological University, Singapore, 31 October 2011.	

LIST OF ACRONYMS

AGIC	Australian Green Infrastructure Council
ASPIRE	A Sustainability Poverty Infrastructure Routine for Evaluation
ASR	Asian Sustainability Rating
BBN	Bayesian belief network
BREEAM	Building Research Establishment's Environmental Assessment Method
BS	Business strategy
CAPM	Capital asset pricing model
CART	Classification and regression tree
CASBEE	Comprehensive Assessment System for Building Environmental Efficiency
CDP	Carbon Disclosure Project
CERES	Coalition for Environmentally Responsible Economies
CMM	Capability Maturity Model
CRC	Cooperative Research Centre
DJSI	Dow Jones Sustainability Index
DPSIR	Driving forces, pressures, states, impacts and responses
EFQM	European Foundation for Quality Management
EIA	Environmental impact assessment
EIRIS	Experts in Responsible Investment Services
EMAS	Eco Management and Audit Scheme
EMH	Efficient market hypothesis
ENV	Environmental
ESG	Environmental, social and governance
FTSE	Financial Times Stock Exchange
GBCA	Green Building Council of Australia
GOV	Governance
GHG	Greenhouse gases
GRI	Global Reporting Initiative
HK-BEAM	Hong Kong Building Environmental Assessment Method

IIRC	International Integrated Reporting Council
IO	Input-output
IP	Internal processes/recognition
IR	Integrated reporting
KLD	Kinder Lydenberg Domini
LCA	Life cycle analysis
LEED	Leadership in Energy and Environmental Design
LTIFR	Lost time injury frequency rate
MPT	Modern portfolio theory
NABERS	National Australian Built Environmental Ratings Scheme
NYSE	New York Stock Exchange
OECD	Organisation for Economic Cooperation and Development
OHS	Occupational health and safety
OHSAS	Occupational Health and Safety Assessment Specification
OPM3	Organisational Project Management Maturity Model
PERT	Program Evaluation and Review Technique
PMMM	Project Management Maturity Model
PSML	Project sustainability maturity level
P3M3	Project, Programme and Portfolio Management Maturity Model
SAM	Sustainable asset management
SE	Stakeholder engagement
SOC	Social
SML	Security market line
SR	Sustainability reporting
SRI	Socially responsible investing
SRTs	Sustainability reporting tools
UN PRI	United Nations Principles of Responsible Investment
WBCSD	World Business Council of Sustainable Development

LIST OF SYMBOLS

α	Daily arithmetic return
β_0	Constant
λ	Daily stock return
BHR	Buy and hold return
COG	Centre of gravity
COV [ ]	Covariance
D	Euclidean distance
deviance	Impurity in nodes for classification tree
Deviance	Impurity in nodes for regression tree
DPS	Dividend per share
DY	Dividend yield
E [ ]	Expected value
EBITDA	Earnings before interest tax depreciation and amortisation
EPS	Earnings per share
ESG	Mean of sustainability performance
EV	Enterprise value
GRAD	Data trend (line of best-fit)
H_o	Null hypothesis
H_a	Alternative hypothesis
NOPLAT	Net operating profit less adjusted taxes
π_i	Absolute state probability of state i, i = 1, 2, … N
p_{ij}	Transition probability from state i to j, i, j = 1, 2.. .m
P	Transition probability matrix with elements p_{ij}
ρ_{ij}	Correlation coefficient between assets i and j
p-value	The likelihood that an outcome observed is by chance
PE	Price to earnings ratio
RGD	Relative graph discrepancy index
ROA	Return on assets

ROE	Return on equity
ROIC	Return on invested capital
r	Correlation coefficient
r^2	Coefficient of determination
STD	Consistency in sustainability performance
t-stat	Test-statistic
TARGET	f (*ESG*, *STD*, *GRAD*)
U_{ij}^2	Chi-square statistic for test for homogeneity
U_i^2	Chi-square statistic for test for stationarity
U^2	Chi-square statistic for test for chain order
Var [ ]	Variance
w	Weighting

ABSTRACT

Sustainability reporting tools (SRTs) have proliferated in order to meet the demand of stakeholders for higher transparency on environmental and social issues. Despite the increasing reliance on SRTs in decision making, much is still unknown about their effectiveness. If SRTs prove to be ineffective, they may pose a serious obstacle to sustainable development as well as to the discourse associated with it. To address this gap, this thesis evaluates the impact of SRTs in the context of companies as well as the building/infrastructure sector, in order to enhance their impact.

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CHAPTER 1 – INTRODUCTION

1.1 Introduction

Following the United Nations Earth Summit (1992) and the aftermath of the Kyoto Protocol (1997), the concept of sustainability has become prioritised as a major socio-political agenda (Fayers, 1998; UNCED, 1992). A plethora of initiatives have been introduced to incorporate sustainability thinking into day-to-day business activities (Koplin et al., 2007; Fowler and Hope, 2007; Gold et al., 2010). These initiatives include a set of reporting formats and indices, such as the Global Reporting Initiative (GRI) (Willis, 2003), Carbon Disclosure Project (CDP) and the Dow Jones Sustainability Index (DJSI), to meet the demand for greater transparency on environmental, social and governance (ESG) issues (Ihlen et al., 2011; Fayers, 1998; Clark and Hebb, 2005; Dando and Swift, 2003; Huang and Kung, 2010; Solomon and Lewis, 2002; Engardio et al., 2007; Hummels and Timmer, 2004; KPMG, 2011; Brown et al., 2009; Dorfleitner and Utz, 2012; Schlegelmilch, 1997; Bassen and Kovacs, 2008; Baker and Nofsinger, 2012; Derwall and Koedijk, 2009). Simultaneously, the building/infrastructure sector has also seen a proliferation of reporting tools – for example, Green STAR, Building Research Establishment's Environmental Assessment Method (BREEAM) and Leadership in Energy and Environmental Design (LEED) to measure the progress towards sustainability (Reed et al., 2009; Crawley and Aho, 1999).

Collectively, these reporting tools for companies and building/infrastructure projects are referred to in this thesis as sustainability reporting tools (SRTs).

Criteria used in SRTs play a role in summarising and condensing enormous complexity to a manageable amount of meaningful information (Godfrey and Todd, 2001; Kessler, 1998; Meadows, 1998). As such, many stakeholders – project managers, institutional investors, society and non-governmental organisations (NGOs) are dependent on SRTs in decision making. The emergence of SRTs sends a message that 'what gets measured gets managed' (Dillenburg et al., 2003, p. 170). For companies, SRTs make it possible to demonstrate results by measuring progress or achievements and clarify consistency between activities, outputs, outcomes and goals. SRTs are also recognised as a 'vehicle' to aid decision making and for comparative performance (Singh et al., 2009; Kessler, 1998).

Project managers use SRTs to not only assess sustainability claims made in projects, but also as an opportunity to discuss major infrastructure policies and identify best practice guidelines (AGIC, 2012). For building owners and operators, using SRTs demonstrates a commitment to corporate social responsibility (CSR), and allows them to stay ahead of future government regulations (GBCA, 2012b). Even social and environmental NGOs demand SRTs because they are driven by their desire to better understand the commitment of a company towards socially responsible practices (O'Dwyer et al., 2005).

Another major stakeholder is the investment community. Rising from the development of SRTs is the emergence of a new market for socially responsible investing (SRI). The SRI market relies on such reporting tools to benchmark the performance of companies and building/infrastructure projects, the latter more commonly known as responsible property investment (RPI). Reporting done by companies may act as an efficient source used for screening in investment decision making (Willis, 2003). The widely held belief of most institutional investors appears to be that better sustainability performance creates intrinsic value for companies and this is expected to translate into market capitalisation (WBCSD and UNEP FI, 2010). According to the European Union on Sustainable Investment Forum (Eurosif, 2010), the SRI market has grown to € 4986 billion as of December 31, 2009, up 338% between 2005 and 2009 (Dorfleitner and Utz, 2012). The Experts in Responsible Investment Services (EIRIS) reports that almost 100 'green' and ethical funds are available to UK investors (2010) while only a dozen of such funds existed over a decade ago (Ballestero et al., 2012). The formation of the United Nations Principles of Responsible Investment (UNPRI) consisting of more than 1000 signatories (as of April 2012) speaks of the growing commitment in this area (UNPRI, 2012). Along the same lines, the Green Building Council of Australia (GBCA) reports that a majority of investors would actually pay more for 'greener' property buildings (GBCA, 2008). A special report by McGrawHill on the construction industry reveals that the 'market for environmentally friendly real estate will be worth approximately $20 billion by 2010' (Arnerich Massena and Associates, 2009, p. 9).

Against this background, it is important that the effectiveness of such reporting tools be investigated. The aforementioned evidence, for example, the growth of the SRI market, seems to suggest that investors do rely heavily on SRTs for investment decision making (Windolph, 2011). Yet, there is still no consensus on the benefits of SRTs. Users of SRTs are unable to provide an indication or clarification that sustainability is affecting market value (Warren et al., 2009). To this end, the speculative impact of SRTs far outweighs rigorous academic research (see Deloitte, 2006; KPMG, 2011b; Boston College Centre for Corporate Citizenship, 2009; Ernst and Young, 2002; KPMG, 2005; McKinsey and Company, 2009) which leaves both valuers and stakeholders in a state of uncertainty because there is a lack of reliable evidence to justify their usefulness (Warren et al., 2009).

This is not helped by sporadic criticisms surrounding SRTs. For example, in the corporate SRT literature, a number of publications (Laufer, 2003; Quirola and Schulp, 2001; Bruno, 1997; Beder, 1998; Walker and Wan, 2011; Roberts and Koeplin, 2007; Ramus and Montiel, 2005) highlight the problem of 'greenwashing', which is a term used to describe a strategy that some companies adopt when communicating with stakeholders on environmental issues without really addressing the issues (Walker and Wan, 2011). The lack of standardised terminology in corporate SRTs (Windolph, 2011) may lead to multiple interpretations of sustainability performance.

Deficiencies with building/infrastructure SRTs have been in the spotlight as well. Fard (2012) maintains that the issue with point-based reporting is that it gives rise to 'point-hunting' where buildings can achieve required points for certification without really having to deal with critical issues of energy efficiency and resource preservation. Chew and Das (2007) argue that points can be lost for credits that are not within the scope of projects. Fowler and Rauch (2006) claim that most frameworks are designed based on expert opinions as opposed to scientific benchmarks of building performance. Lozano and Huisingh (2011) criticise current approaches for compartmentalising economic, environmental and social criteria, arguing that they neglect possible synergies (either positive or negative) across the criteria.

In addition, most corporate and building/infrastructure SRTs adopt a deterministic approach where a criterion or sub-criterion receives a single score and the highest combined score is typically perceived as representing better sustainability performance. Baumgärtner and Quaas (2009, p. 2009) reason that this approach may no longer be valid as the sustainability concept is related to the future and good planning for sustainability should be 'operationalised for conditions of uncertainty'. Researchers (Insua and French, 1991; Wolters and Mareschal, 1995; Hyde et al, 2005; Hyde et al., 2004) demonstrate that uncertainty needs to be incorporated into decision making processes due to its influence on the ranking of alternatives (see also Flug et al., 2000; Netto et al., 1996; Tecle et al., 1988).

Viewing such criticisms, a few contributors have raised the need for more research in this area. For example, Engshuber (2011), the Chair of the United Nations Principles of Responsible Investment (UNPRI) and the Prince's Accounting for Sustainability Project (A4S) have called for better models and robust tools to not only improve on current sustainability measurements but also help integrate sustainability into mainstream investment decision making (Fries et al., 2010). UNPRI (2012) adds that the evidence base for the integration of sustainability issues into investment research remains relatively underdeveloped. This is also consistent with the view of Runde and Thoyre (2010) that the integration of sustainability into real estate valuation is still at a premature phase.

In considering the use of SRTs for decision making, there are two important research questions which need to be addressed.

RQ1. What is the impact, in terms of effectiveness, of SRTs?
RQ2. How can deficiencies in SRTs be reduced?

This thesis attempts to provide answers to both these research questions. The impact of SRTs is evaluated by conducting a thorough literature review to identify deficiencies in current SRTs, examining the link between ESG scores and financial performance, exploring the behaviour (price movement, index trend and trading volume) of the FTSE4Good Index and its constituents, examining the effectiveness of building SRTs (i.e. uncertainty analysis; post-occupancy evaluation; characteristics of sustainability awards) and exploring the state of sustainability reporting. From these findings, it may then be possible to draw conclusions about their usefulness and ultimately their contribution to the set up of the 'green' economy defined as: 'an economic system that is compatible with the natural environment, is environmentally friendly, is ecological and for many groups, socially just; dominated by investing in, producing, trading, distribution and consuming sustainable products and services' (Fulai, 2010, p. 1).

To address the second research question (RQ2), this thesis proposes alternative ways to enhance the impact of SRTs applicable to both companies and building/infrastructure projects. It presents an original framework for sustainability reporting and introduces a tree form classification model to distinguish the sustainability performance of companies. This framework, which accounts for uncertainty in sustainability reporting, is later extended to portfolio analysis where more than one company/project is involved. Also, the sustainability maturity of companies and projects are modelled given that most SRTs fail to capture nuances in sustainability practices. These tools designed for a wide range of stakeholders (institutional investors, government departments and individuals), are distinctive contributions to assist in decision making. Company or project managers may also wish to use some of these tools to help benchmark and better characterise sustainability performance.

1.2 Terminology – sustainability and sustainability reporting

Because the literature is not always consistent in the usage of sustainability terminology (Constanza and Patten, 1995; Pope et al., 2004; Adams and Larrinaga-Gonzalez, 2007), there is a need to firstly clarify the meanings of the terms used in this thesis.

Sustainability. Attempts by many writers to come up with an operational definition of sustainability have made the term ambiguous, and this is not helped by lay meanings found in dictionaries. Commonly, sustainability is used interchangeably with the term sustainable development. There are many attempts to particularise this definition, including the triple bottom line concept of Elkington (1998) in economic, social and environmental pillars (Bell and Morse, 2003), corporate social responsibility (CSR), corporate sustainability (CS) as well as more recently the term environmental, social and governance (ESG). A few of these terms are defined here for the reader.

CSR. CSR is defined as a continuing commitment by companies to behave ethically and contribute to economic development, while improving the quality of life of the workforce and their families as well as the community at large (Moir, 2001). It is closely tied to stakeholder theory (Freeman and Evan, 1990) where proponents claim that longer-term profits can be made if companies operate with an ethical mindset.

CS. van Marrewijk (2003) suggests CS as the ultimate or overarching goal of meeting the needs of the present without compromising the ability of future generations to meet their own needs. In this definition, CSR is seen as an intermediate stage where companies attempt to balance the triple bottom line towards meeting CS.

ESG. ESG terminology is widely used in responsible investment reports (see Briand et al., 2011; RIAA, 2010). ESG refers to non-financial information, specifically environmental, social and governance issues faced by companies (Bassen and Kovacs, 2008). It is believed that incorporating ESG into investment practices can yield better financial performance (Himick, 2011).

As well, numerous definitions exist on sustainability reporting with no single universally accepted definition. The subsequent sections broadly define sustainability reporting for both corporate and buildings/infrastructure in line with the scope of this thesis. Chapters 2 and 3 will explore in more depth the nature of specific SRTs.

1.2.1 Corporate sustainability reporting

According to KPMG (2008), corporate sustainability reporting simply refers to a company's reporting on its performance in three areas: economic, social and environmental. GRI (2006) defines sustainability reporting as a practice of measuring, disclosing and being accountable to both internal and external stakeholders towards achieving sustainable development. Daub et al. (2003) claim that such a report must have both quantitative and qualitative information focusing on the extent by which a company has managed to improve its economic, environmental and social effectiveness. The World Business Council for Sustainable Development (WBCSD) defines sustainable development reports as publicly-available reports where companies inform stakeholders of their current position and agenda surrounding the aforementioned areas (WBCSD, 2002).

Other terms that are used synonymously with such reporting are triple bottom line (TBL) reporting, corporate social responsibility (CSR) reporting, environmental, social and governance (ESG) reporting, sustainable development (SD) reporting and integrated reporting (IR).

Triple bottom line reporting. The Group of 100 (2003), an association of senior accounting and finance executives which represents major companies as well as government-owned enterprises in Australia, uses the 'Triple Bottom Line (TBL) reporting' to denote any form of communication regarding environmental, social and economic issues to stakeholders. In this definition, it is not assumed that a publicly-available TBL report is the only means by which communication of such information can be done but also includes various sources such as websites or discussion forums. TBL reports must also be linked closely with business strategy or risk being meaningless. Painter-Morland (2006) maintains that TBL reporting addresses main issues surrounding global codes of conduct and that the three concepts underlying it, namely stakeholder engagement, organisational integrity and stakeholder activism, can be used to formulate a 'social grammar that would place businesses in a more sustainable relationship with society' (Painter-Morland, 2006, p. 353).

Corporate social responsibility (CSR) reporting. CSR reporting has been referred to as the external reporting of social, ethical and environmental aspects of a business. Gray et al. (1987) refer to it as a process of communicating social and environmental issues to particular interest groups in society.

ESG reporting. The Financial Services Council (FSC) and Australian Council of Super Investors (ACSI) defines ESG reporting as one which encompasses three main criteria – environmental, social and corporate governance – spanning across various issues such as climate change, environmental management systems, efficiency (waste, energy, water), workplace occupational health and safety, human capital management, corporate conduct and stakeholder engagement (FSC and ACSI, 2011).

Sustainable development (SD) reporting. The New Zealand Business Council for Sustainable Development (NZBCSD) (2002) suggests that sustainable development reporting is a tool which companies can use to assist with the identification of economic, environmental and social impacts as well as help assess and monitor their progress towards achieving the goal of sustainable development.

Integrated reporting (IR). An integrated report is defined by the International Integrated Reporting Council (IIRC) as 'a concise communication about how a company's strategy, governance, performance and prospects, in the context of its external environment, lead to the creation of value in the short, medium and long term' (IIRC, 2013, p. 7). Currently, the IR framework is still under development.

1.2.2 Buildings/Infrastructure sustainability reporting

For buildings/infrastructure, sustainability reporting describes a format of assessment concerning features of new or existing building/infrastructure (Baird, 2009).

Cole (1999) suggests that building/infrastructure sustainability reporting usually takes on a few common characteristics: 'emphasise on the assessment of resource use and ecological loadings; assess design intentions and potential through prediction rather than actual real world performance; use of performance scoring as an additive process; and have a performance summary in the form of a certificate or label that can be part of a leasing document' (Cole, 1999, p. 457). Cole (2005) adds that such reports are not only a means to facilitate the reduction of environmental impacts, but are also increasingly used as a basis for risk and real estate valuations in obtaining development approval from the banking industry.

The terminology often used in the buildings/infrastructure sector to refer to sustainability reporting are 'green' building reporting/rating, sustainability rating and sustainable infrastructure rating.

'Green' building reporting/rating. A few definitions are available. According to Ali and Al Nsairat (2009, p. 1053), a 'green' building rating provides an 'effective framework for assessing building environmental performance and integrating sustainable development into building and construction processes'. They add that using 'green' building rating in the design/build phase will result in significant benefits which are not likely to come from standard practices. Furr et al. (2009, p. 219) claim that 'green' building rating are 'critical among local governments to promote sustainable development'. Kibert (2008, p. 55) refers to 'green' building rating as a tool that rates the 'effects of a building's design, construction and operation, among them environmental impacts, resource consumption and occupant health'.

Sustainability rating. Raniga and Wasiluk (2007) define sustainability rating as tools that focus on different aspects of sustainable development such as life cycle cost assessment, life cycle costing, energy system design, performance evaluation as well as for operations and maintenance optimisation. They could also deal with different stages of a project such as planning, design and post-construction.

Sustainable infrastructure rating. Refers to a tool used to rate the sustainability performance or expected performance of an infrastructure (Fowler and Rauch, 2006).

1.3 Thesis contributions

This thesis is distinctive and original because it adopts a 'transdisciplinary' perspective in approaching the two research questions. A 'transdisciplinary' research, following the definition of Rosenfield (1992), is a branch of study which discusses common problems or issues confronting two or more areas of discipline. In a similar manner, this research focuses on investigating the impact of SRTs and proposes solutions applicable to both the corporate and the building/infrastructure sector. The rationale for selecting such an approach is because (i) firstly, the degree of integration in a complex field such as sustainability is still limited (Sahamie et al., 2013); and (ii) secondly, there are common issues between corporate and building/infrastructure SRTs as highlighted in Chapters 2 and 3.

The analytical techniques adopted in this thesis are content analysis, linear and multi-linear regression analysis, portfolio analysis, Markov chains, agglomerative hierarchical clustering, classification and regression tree (CART) technique, second order moment, Bayesian belief network (BBN) and the fuzzy-based approach due to their suitability in meeting the requirements of the research design. These techniques are discussed in the various chapters of this thesis where they are used. In addressing the research questions, the contributions of this thesis include:

Evaluation:

- The conduct of an empirical study to test the proposition that a strong positive link exists between ESG and financial performance. Data analysed are based on the Top 300 companies in Australia. The study finds a weak correlation between ESG and financial performance measured using a range of financial ratios. The portfolio of ESG leaders does not outperform the portfolio of ESG laggards. Although a negative relationship is detected between analysts' forecast error and ESG, the results are not statistically significant.
- The conduct of an empirical study to examine the behaviour (price movement, index trend and trading volume) of the FTSE4Good Australia Index and its constituents using Markov chains. The findings from this study demonstrate that selecting company stocks that are rated more highly in ESG may not necessarily lead to

superior performance. Sustainability indices on the other hand are found to be stationary and have a marginally higher probability of experiencing a positive percentage change.

- An exploration of the effectiveness of building SRTs via a three-part study. Some of the findings from this study are: variation in criteria scores and weights need to be accounted for in building SRTs; there is no large difference in occupants' satisfaction levels between a sustainable (ascertained by building SRTs) and a non-sustainable building; and criteria scores are inconsistent for buildings with similar sustainability awards. This may possibly suggest that current building SRTs are deficient and may not be able to distinguish the value between a sustainable and a non-sustainable building. Extra care would be needed in interpreting the outcomes of building SRTs.
- An exploration of the state of sustainability reporting across publicly-listed Australian construction companies. Findings from this study show that construction companies still have poor reporting standards and evidence of graph obfuscation is largely present in this industry sector.

Enhancement:

- The proposal of an original and alternative multi-criteria framework (applicable to companies and the building/infrastructure sector) to assess sustainability performance. This framework encompasses six elements: (i) Criteria selection; (ii) Quantitative measurement scales for the criteria; (iii) Characterising each criterion by measures of central tendency and dispersion; (iv) The distinction of additionality; (v) Criteria weighting; and (vi) Combining criteria to give an overall sustainability score characterised by a measure of central tendency and a measure of dispersion.
- The development of a classification tree model for companies based on KLD's scoring tool. The methodology uses a combination of both agglomerative hierarchical clustering as well as the classification and regression tree (CART) techniques. Given the availability of many other ESG scoring tools such as KLD, EIRIS, SAM and ASR each with its own scoring scale, a generic regression tree model encompassing three normalised criteria (namely *ESG* – a measure of sustainability performance, *STD* – a measure of performance consistency, and *GRAD* – a measure of data trend) is further proposed. This generic regression tree

model is then validated against random samples selected from the New York Stock Exchange (NYSE). Results demonstrate that this model is promising and can act as a reliable tool for distinguishing companies' ESG performance. Although the example given in this chapter is based on companies, the method proposed can be easily extended to classify the sustainability performance of building/infrastructure projects.

- The proposal of a model to establish the link between different levels of sustainability maturity and sustainability performance ('Leader', 'Average' and 'Laggard'). Results from the sustainability maturity assessment are then fed into the Bayesian belief network (BBN) analysis to explore the link between sustainability maturity and financial performance.
- The proposal of a set of criteria to measure project sustainability maturity levels (PSML). The criteria spans across areas such as project integration, scope, cost, human resource management, communication and procurement. The fuzzy-based approach is then used to demonstrate the assessment of PSML.
- The introduction of an original method to integrate ESG into traditional portfolio analysis is introduced. While the nature of return–risk efficient portfolio frontier has been discussed at length in the literature, it has not been extended to incorporate the analysis of ESG issues. The framework here is the first attempt to do so. Several other concepts such as the centre of gravity (COG) and Euclidean distances are used to help differentiate the superiority of portfolios accounting for both return–risk and ESG–variance.

1.4 Thesis outline

Figure 1.1 shows the overall thesis organisation and the link between different chapters. Chapters 2 and 3 are reviews of the state-of-the art on sustainability reporting, divided into two broad categories – Corporate SRTs and Building/Infrastructure SRTs. A comparative analysis and detailed critique of these reporting tools are done to further identify their limitations.

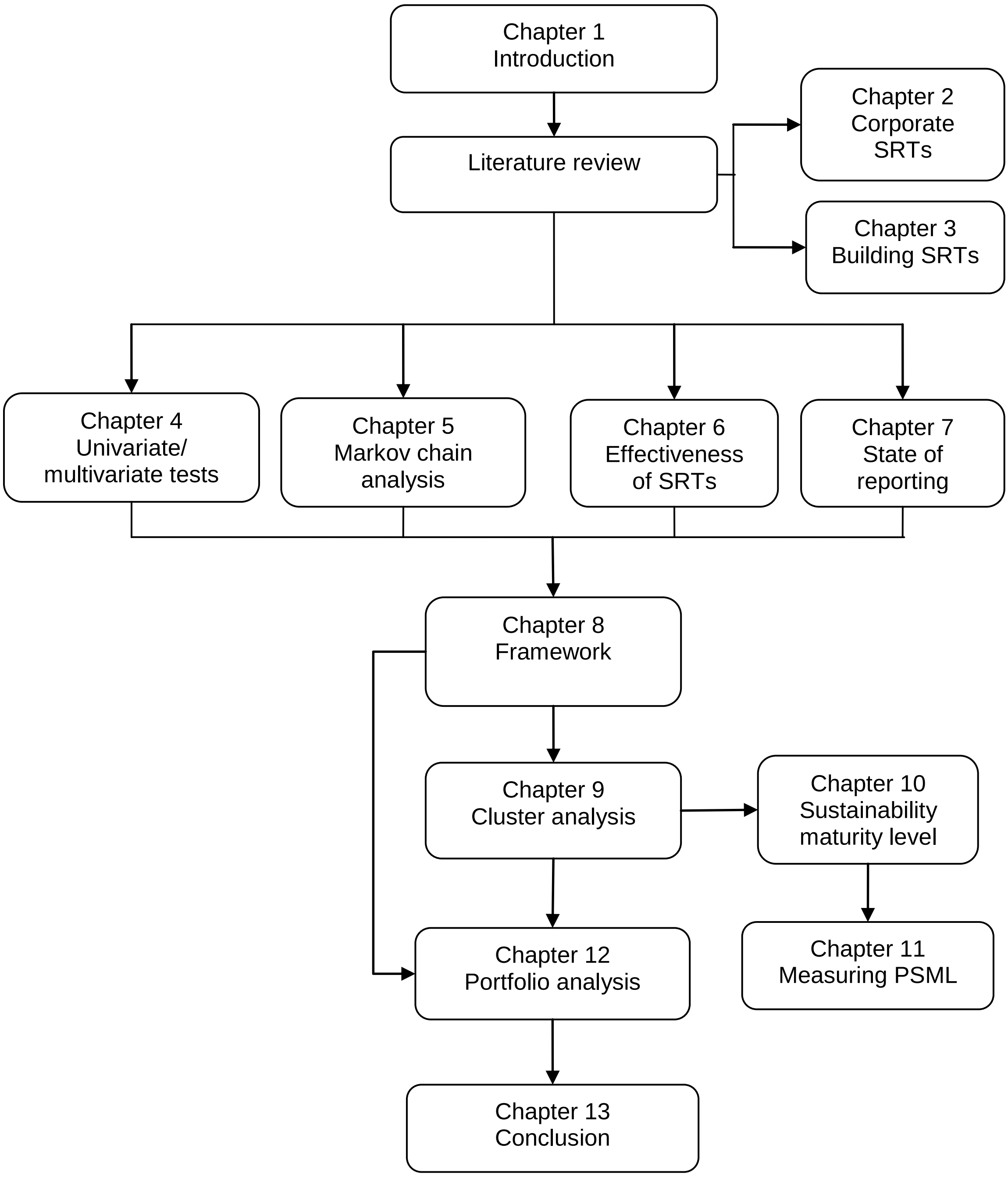


Figure 1.1 Structure of thesis.

Chapter 4 examines the relationship between ESG and financial performance. Linear and multi-linear regression techniques are used for year on year, 1-year lag and 2-year lag analyses. Portfolio analysis is conducted for ESG leaders and laggards. Analysts' forecasts error for both the 1-year and 2-year horizons are also analysed for the sample data (top 300 companies in Australia).

Chapter 5 further explores the behaviour (price movement, index trend and trading volume) of the FTSE4Good Australia Index and its constituents using Markov chains. The states are defined as follows: stock prices – intervals which reflect on price differences between 10-day moving averages and daily closing prices; trading volume – intervals which reflect on the percentage differences between 10-day average volume and daily trading volume; stock index – toggling between an increasing trend (if the change in share index is more than 0) and decreasing trend (if change in share index is less than 0). This helps in making probabilistic statements of being in any given state and helps draw conclusions on the value relevance of investing in more highly valued ESG indices/stocks. Tests of stationarity, order and homogeneity are also conducted.

Chapter 6 examines the effectiveness of building SRTs via a three-part study: uncertainty analysis; post-occupancy evaluation; and characteristics of sustainability awards. This study reveals that the variation in criteria scores and weights need to be accounted for in SRTs; there is no large difference in occupants' satisfaction levels between a sustainable building (ascertained by building SRTs) and a non-sustainable building; and criteria scores are inconsistent for buildings with similar sustainability awards.

Given that a weak relationship is detected between ESG scores and financial performance, there is a need to obtain some insights of the state of reporting by which these scores are derived. This could possibly be an explanation for the mixed results obtained in Chapters 4 and 5.

As such, Chapter 7 explores the state of sustainability reporting across publicly-listed Australian construction companies. Euclidean distances are used to measure the discrepancy between actual disclosures and expectations of institutional investors. The findings show that a majority of Australian construction companies still have reporting that is below expectations of institutional investors. Evidence of graph obfuscation is found.

Chapter 8 proposes an original and alternative framework for companies and building/infrastructure reporting which leverages on the concept of second order moment. The framework allows for a better characterisation of sustainability as it now incorporates uncertainty into measurements.

Chapter 9 extends the framework in Chapter 8 by proposing a model to classify companies based on their sustainability performance. Hierarchical clustering as well as classification and regression tree (CART) techniques are used to develop three main clusters 'Leader', 'Average' and 'Laggard' (based on companies' ESG performance). A generic regression tree model encompassing three normalised criteria (*ESG*, *STD* and *GRAD*) is also proposed. These models are useful as they help with the standardisation of existing terminology.

Following the ontological contribution in Chapter 9, Chapter 10 attempts to establish the link between sustainability maturity levels (ad hoc, defined, managed and integrated) and the different clusters of companies ('Leader', 'Average' and 'Laggard'). The relationship between sustainability maturity levels and financial performance of companies is further explored through a BBN analysis.

Chapter 11 turns attention to measuring project sustainability maturity levels (PSML). In particular, this chapter makes a contribution by (i) recommending a set of criteria (spanning across project management areas such as integration, scope, cost, human resource management, communication and procurement) differentiated by sustainability maturity levels and (ii) presenting the fuzzy-based approach to assess PSML.

Chapter 12 proposes a method which combines the framework introduced in Chapter 8, classification tree model presented in Chapter 9, Markowitz's modern portfolio theory, centre of gravity (COG) and Euclidean distances to help differentiate the superiority of portfolios accounting for both return–risk and ESG–variance.

Finally, Chapter 13 summarises the main findings and conclusions from this study. Future research directions which others can take to build on the present study are discussed accordingly. This is followed by relevant appendices which provide supplementary information derived from this research.

CHAPTER 2 – A REVIEW OF CORPORATE SUSTAINABILITY REPORTING TOOLS (SRTs)

2.1 Introduction

Despite the multiplicity of sustainability definitions, there is a common understanding that to gauge how a company is doing with respect to sustainability, it should be measurable (Özdemir et al., 2011). This has been the key motivator for the development of corporate sustainability reporting tools (SRTs), which, like sustainability, is also known with various terminology – corporate social responsibility (CSR) reporting, sustainable development (SD) reporting, triple bottom line (TBL) reporting, non-financial reporting, and environmental, social and governance (ESG) reporting as defined in Chapter 1.

While it may be argued that different corporate SRTs are required to cater for the different nature of businesses, climates, cultures and resources, the rapid growth in SRTs has made understanding them a very complicated exercise. This chapter aims to provide the necessary background on corporate SRTs for the analysis in subsequent chapters.

This chapter does not serve to replace but rather complement existing reviews that have been done in this area. Adams and Narayanan (2007) focus primarily on governing bodies that promote sustainability reporting guidelines. Escrig-Olmedo et al. (2010) provide a review of ESG scores and third-party agencies. This chapter provides a more holistic approach encompassing three mainstream SRTs (frameworks; standards; scores and indices). The following sections explore, respectively, the nature and characteristics of these corporate SRTs. Then, a critique of these tools and conclusions from the review are given.

2.2 Corporate SRTs

Corporate SRTs can be divided into the following: frameworks; standards; scores and indices, as shown in Figure 2.1. Frameworks typically refer to principles, initiatives or guidelines provided to companies to assist them in their disclosure efforts. Standards have similar function as frameworks but exist in the form of more formal documentation that spell out the requirements and specifications that can be used to ensure that sustainability efforts are consistently achieved. Scores and indices are third-party reporting of a company's sustainability or ESG performance. A review of these tools is provided in this chapter.

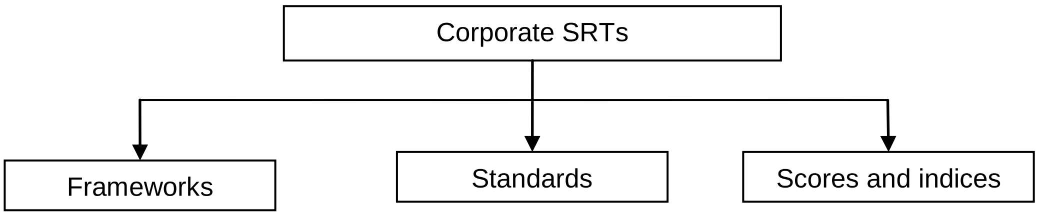


Figure 2.1 Corporate SRTs.

2.2.1 Frameworks

Global Reporting Initiative (GRI)

The GRI was founded in 1997 by the Coalition for Environmentally Responsible Economies (CERES) with the intention of creating a globally applicable sustainability reporting framework (GRI, 2011). Since then, two subsequent versions of the third generation GRI guidelines have been issued, namely G3 and G3.1 (an updated version of G3). A multi-stakeholder consultation approach is used to create the G3.1 guidelines with a stronger emphasis on clarity, purpose of criteria as well as the process of reporting. Sector supplements which are reporting guidelines specifically prepared for different industry sectors are also available. More recently, a fourth generation guideline (G4) has been developed. G4 includes proposed changes to themes, such as anti-corruption and greenhouse gas (GHG) emissions, and is expected to be launched in

May 2013. These guidelines are not legally binding and are voluntary in nature (Adams and Narayanan, 2007).

According to the GRI guidelines, a typical report should address the following: vision and strategy; company profile; governance structure and management systems; GRI content index; and performance criteria (economic, social and environmental) (Adams and Narayanan, 2007). Performance criteria are divided into either 'core' or 'additional'. 'Core' criteria are intended to identify generally applicable criteria and are assumed to be material to most companies whereas 'additional' criteria refer to emerging practices that may or may not be applicable to all companies. Materiality is defined in GRI guidelines as criteria that reflect the companies' significant economic, environmental, and social impacts or that would substantively influence the assessments and decisions of stakeholders (GRI, 2011). There are three application levels, namely A, B and C depending on companies' extent of disclosures, and also takes into account whether the report produced has received third-party verification in which case it will be given a '+'. Table 2.1 shows the performance criteria requirement for each of the application levels.

Application Level	**C**	**C+**
Performance Criteria	Report on a minimum of 10 performance criteria including at least one from each of : economic, social and environmental	All requirements in C and report is externally assured.
Application Level	**B**	**B+**
Performance Criteria	Report on a minimum of 20 performance criteria, at least one from each of economic, environmental, human rights, labour, society and product responsibility.	All requirements in B and report is externally assured.
Application Level	**A**	**A+**
Performance Criteria	Report on all core G3 criteria and sector supplement criteria based on the materiality principle. Explanation must be provided if criteria are omitted.	All requirements in A and report is externally assured.

Table 2.1 GRI application levels (GRI, 2011).

Chester and Woofter (2005) claim that the number of companies using GRI's guidelines has been increasing and attribute this to several reasons:

- Demand for social and environmental criteria. Chester and Woofter (2005) point out that a company adopting GRI guidelines may be able to efficiently reduce the time and effort spent responding to demand for disclosures on social and environmental criteria.
- GRI-based reports are superior. 'Several studies have shown that GRI users score higher than non-users in a benchmark of overall quality of sustainability reports' (Chester and Woofter, 2005, p. 19).

SIGMA Project

The SIGMA Project describes a four-phase cycle (leadership and vision; planning; delivery; monitor, review and report) broken down into three to five levels each to manage and embed sustainability within a company. These phases and their purposes are described in Table 2.2.

Management phases	Purposes
Leadership and vision • LV1: Business case and top-level commitment • LV2: Vision, mission and operating principles • LV3: Communication and training • LV4: Culture change	• Develop a business case to address sustainability and secure top-level commitment to integrate sustainability into core processes. • Identify stakeholders and open dialogue with them on key impacts. • Formulate company's long-term strategy. • Raise awareness of sustainability. • Ensure corporate culture is supportive of move towards sustainability.
Planning • P1: Performance review • P2: Legal and regulatory analysis and management • P3: Actions, impacts and outcomes • P4: Strategic planning • P5: Tactical planning	• To ascertain company's current sustainability performance, legal documents and voluntary commitments. • Identify and prioritise company's key areas of sustainability. • Develop strategic plans to deliver company's vision. • Engage with stakeholders on plan. • Formulate tactical short-term plans to support sustainability objectives.
Delivery • D1: Change management • D2: Management programmes • D3: Internal controls and external influences	• Align and prioritise management programs in line with company's sustainability vision. • Ensure appropriate internal controls are in place. • Improve performance by delivering sustainability strategies and action plans. • Exercise appropriate external influence on suppliers, peers and others to advance sustainable development.
Monitor, review and report • MMR1: Monitoring, measurement, auditing and feedback • MRR2: Tactical and strategic review • MRR3: Reporting progress • MRR4: Assurance of reporting	• Monitor progress against stated values, strategies and performance objectives. • Engage with internal and external stakeholders via reporting and assurance.

Table 2.2 Sigma four-phase management framework (SIGMA Guidelines, 2008, p. 6).

DPSIR Framework

Kristensen (2004) describes the DPSIR framework as a chain of causal links beginning with a set of driving forces (i.e. economic sectors; human activities) that translates into pressures on the environment (i.e. waste; pollution; emissions). These pressures affect the physical, chemical and biological states of the environment and bring harmful impacts not only on the ecosystem but also on human health. Responses from stakeholders (i.e. prioritisation; target setting for criteria; policies) are then needed to eliminate these harmful impacts (Kristensen, 2004). This framework is an extension of the pressure-state-response model (see OECD, 2003) in the 1970s and is adopted by the Organisation for Economic Cooperation and Development (OECD) (UNEP, 2006). It is also currently used as an integrated approach for reporting by the European Environment Agency (EEA). Figure 2.2 illustrates, in more detail, the relationships between the causal links. The driving force is defined as a need; for example, the driving force for an individual would be to seek shelter, food and water. Driving forces motivate human activities, such as transportation or food production which exert pressures on the environment, for example, direct emissions, production of waste and noise. As a direct consequence of these pressures, the physical, chemical and biological states of the environment are affected (air quality; water quality; and soil quality among others). Changes in these states impact the quality of the ecosystem. As a result of these impacts, responses from either society or policy makers are required (Kristensen, 2004). These responses have the potential to influence any part of the DPSIR chain.

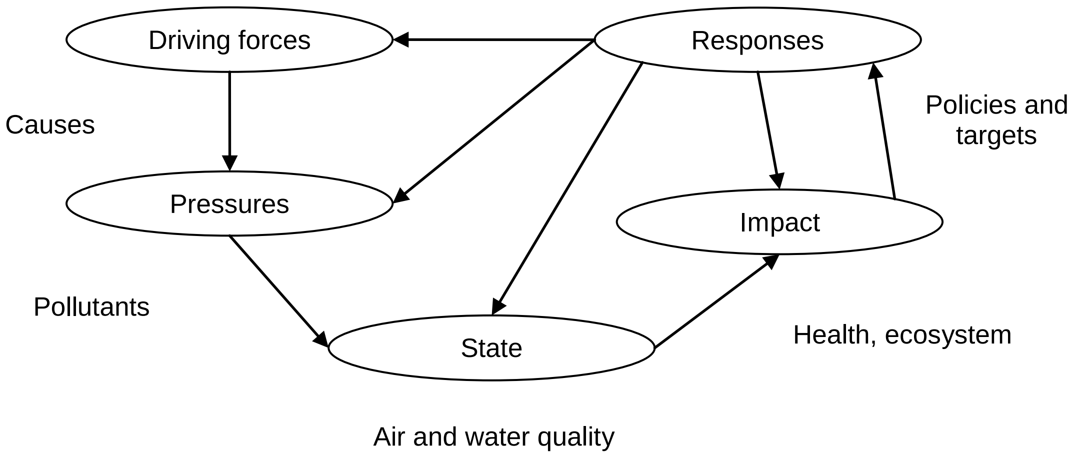


Figure 2.2 DPSIR framework (Kristensen, 2004).

The Global Compact

The 10 principles of the United Nations Global Compact (UNGC) span across criteria such as human rights, labour, environment and anti-corruption. It seeks the co-operation of companies to embrace and support these principles within their sphere of influence. These principles are (UNGC, 2011):

Human rights:

- Principle 1: Companies should support and respect the protection of internationally-acclaimed human rights.
- Principle 2: Make sure that they are not complicit in human rights abuses.

Labour:

- Principle 3: Companies should uphold the freedom of association and the effective recognition of rights to collective bargaining.
- Principle 4: The elimination of all forms of forced and compulsory labour.
- Principle 5: The effective abolition of child labour.
- Principle 6: The elimination of discrimination in respect of employment and occupation.

Environment:

- Principle 7: Companies should support a precautionary approach to environmental challenges.
- Principle 8: Undertake initiatives to promote greater environmental responsibility.
- Principle 9: Encourage development and diffusion of environmentally friendly technologies.

Anti-corruption:

- Principle 10: Companies should work together against corruption in all its forms, including extortion and bribery.

Carbon Disclosure Project (CDP)

The CDP is an independent non-profit company which holds one of the largest databases on disclosure of greenhouse gas emissions, water use and climate change strategies. CDP claims that the scores it provides are merely on the quality of environmental disclosures and are not an indicative measure of corporate sustainability performance (CDP, 2010). The criteria considered under CDP include: company-specific risks; potential opportunities arising from climate change; and good internal data management practices to help companies understand their GHG emissions. The carbon disclosure scores are normalised to a 100-point scale (see CDP, 2010). The indicative meanings for the range of scores are described in Table 2.3.

High (> 70)	**Mid-range (50–70)**	**Low (< 50)**
A high score typically indicates one or more of the following: • Strong understanding and management of company specific exposure to climate related risks and opportunities. • Strategic focus and commitment to understanding criteria related to climate change, emanating from the top of the company. • Ability to measure and manage the company's carbon footprint. • Regular and relevant disclosure to key company stakeholders.	A mid-range score typically indicates one or more of the following: • Growing maturity in understanding and managing company-specific risks and potential opportunities related to climate change. • Good evidence of ability to measure and manage carbon footprint across global operations. • Commitment to the importance of transparency.	A low score typically indicates one or more of the following: • Relatively new commitment to understanding climate-related criteria • Limited ability to disclose known risks or potential opportunities related to climate change • Limited ability to measure and manage the company's carbon footprint. • Possible reluctance to disclose certain requested information due to commercial sensitivity.

Table 2.3 Scoring framework for CDP (CDP, 2010).

World Business Council for Sustainable Development (WBCSD)

The World Business Council for Sustainable Development (WBCSD) consists of the world's leading companies across a wide range of industry sectors. WBCSD offers a range of tools to support the embedment of sustainability into corporate strategy and operations, such as the GHG Protocol, Sustainable Forest Finance Toolkit and the WBCSD Measuring Impact Framework among others. Of particular significance is the WBCSD Measuring Impact Framework which started in 2006 as a result of WBCSD member companies requesting a framework that could help them measure the impact at any stage in the life cycle of an operation, unlike traditional Environmental Impact Assessments (EIAs) which are carried out more for due diligence (WBCSD and IFC, 2008). The outcome is a framework which is rooted in an approach that measures what a company does across four criteria, namely governance and sustainability, assets, people and financial flows. This framework adopts a four-step methodology as shown in Figure 2.3.

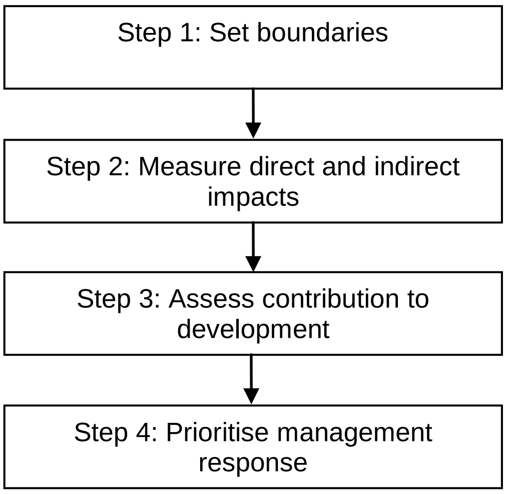


Figure 2.3 WBCSD measuring impact framework (WBCSD and IFC, 2008).

Greenhouse Gas Protocol (GHG Protocol)

Greenhouse Gas (GHG) Protocol was initiated through a joint-collaboration between the World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI) to develop effective programs for tackling climate change. The GHG Protocol Corporate Accounting and Reporting Standard (WBCSD and WRI,

2004) provides a step-by-step guide for companies to quantify and report on their emissions. These steps include: setting corporate goals and inventory; setting company boundaries – deciding whether an equity share approach or control approach should be adopted (see WBCSD and WRI, 2004 for details); setting operational boundaries - understanding scope 1, 2, and 3 emissions of a company; tracking emissions over time; managing inventory quality; accounting for GHG reductions; verifying GHG emissions and setting GHG targets.

Broad principle-based frameworks

Six broad principle-based frameworks which fulfil two attributes – (i) have been in existence for at least five years and (ii) implemented on a global scale are compared here (Kessler, 1998):

- Natural Step
- Natural Capitalism
- Ecological Footprint
- CERES
- Sustainable Process Index
- 2001 Environmental Sustainability Index

The underlying principles behind these frameworks and their level of comprehensiveness (that is, whether these frameworks cover all three main sustainability criteria – economic, social and environmental) are summarised in Table 2.4.

Principle-based frameworks	Principles	Does it cover all three criteria (economic, social and environmental)?
Natural Step	• Applies scientific principles/laws of nature to justify whether an act is sustainable.	• No. Just environmental criterion.
Natural Capitalism	• On the basis that an economy requires human, financial, manufactured and natural capital to function.	• Yes.
Ecological Footprint	• Ecological footprint introduced as an accounting concept for ecological resources.	• No. Just environmental criterion.
CERES	• Represents a commitment for companies to make continuous improvements and be accountable for their business activities.	• Yes.
Sustainable Process Index	• Primary focus is on anthropogenic material flows, renewable resources and the sustenance of a variety of species and landscapes.	• No. Just environmental criterion.
2001 Environmental Sustainability Index	• Components of environmental sustainability include environmental systems, reducing environmental stress, reducing human vulnerability and global stewardship.	• No. Just environmental criterion.

Table 2.4 Summary of sustainability frameworks (Kessler, 1998).

Only two out of six of these frameworks (Natural Capitalism and CERES) incorporate the triple bottom line concept on sustainability (Elkington, 1998). The others (natural step, ecological footprint, sustainable process index and 2001 Environmental Sustainability Index) are predominantly focussed on the environment, neglecting both social and economic criteria. CERES has been translated into what is now known as the Global Reporting Initiative (GRI).

2.2.2 Standards

Standards exist to provide guidelines on best-in-class practices, some more specific than others. For example, standards that cover the social criteria are OECD Guidelines for Multinational Enterprises, UN Global Compact, EFQM, OHSAS 18001, AS/NZS 4801 and SA8000. Guidelines on the management of environmental criteria can be found across standards such as ISO14001 and EMAS. Table C1 (in Appendix C) summarises the incorporation of such standards across SRTs (Escrig-Olmedo et al., 2010). Only brief descriptions of some of the main standards are provided here; for details of other standards not covered in this chapter, see Escrig-Olmedo et al. (2010).

AA1000

The primary aim of the AA1000 (2008, p. 8) is to 'provide organisations with an internationally accepted, freely available set of principles to frame and structure the way in which they understand, govern, administer, implement, evaluate and communicate their accountability'. There are three principles in AA1000, namely the 'Principle of Inclusivity', the 'Principle of Materiality' and the 'Principle of Responsiveness'.

A company is considered to adhere to the 'Principle of Inclusivity' (AA1000, p. 11) when:

- It is committed to be accountable to those whom it has an impact on.
- It has in place a process for stakeholder participation (identifying and understanding stakeholders; identifying, implementing and developing appropriate, robust and balanced engagement strategies; establishing ways for stakeholders to be involved in decisions that serve to improve sustainability.
- It has in place necessary competencies and resources to conduct the process for stakeholder participation.
- The engagement with stakeholders results in them developing and achieving an accountable and strategic response to sustainability.

Adherence to the 'Principle of Materiality' is when a company (AA1000, p. 13):

- Has a materiality determination process in place (determines criteria from a wide range of sources such as the needs and concerns of stakeholders, societal norms and financial considerations).
- Has in place or access to the necessary competencies and resources to apply the materiality determination process.
- The materiality determination process leads to a balanced understanding and prioritisation of material sustainability criteria.

A company is considered to adhere to the 'Principle of Responsiveness' (AA1000, p. 15) if it:

- Has in place a process for developing responses.
- Has access to necessary competencies and resources that would assist the company in achieving their commitments.
- Respond in a comprehensive (addresses the needs, concerns and expectations of stakeholders), balanced and timely manner.
- Has a process in place to communicate with stakeholders.

SA8000

The aim of SA8000 is to provide a standard according to international human rights norms and national labour laws so that employees within a company can stay protected and empowered. Other standards also addressing similar issues (not covered here) are ILO Convention 1 (Hours of Work), ILO Convention 29 (Forced Labour), ILO Convention 87 (Freedom of Association), Universal Declaration of Human Rights, The International Covenant on Economic, Social and Cultural Rights, among others (SA8000, 2008). Given the existence of these standards, questions arise as to which standard dominates (or would be applicable) if a company had adopted all of them. The SA8000 guideline provides a resolution by clearly stating that 'a company shall comply with national and all applicable laws, prevailing standards and other requirements to which the company subscribes, and this standard (SA8000). When such and other applicable laws, prevailing industry standards, and other requirements to which the company subscribes, and this standard address the same issue, the provision most favourable to workers shall apply' (SA8000, 2008, p. 4).

The nine main criteria covered under SA8000 are child labour, forced and compulsory labour, health and safety, freedom of association and right to collective bargaining, discrimination, disciplinary practices, working hours, remuneration and management systems.

ISO 14001

ISO 14001:2004 provides a generic requirement for environmental management, which can be used as a common reference for communicating about environmental criteria with stakeholders. The standard itself does not specify the levels of environmental performance because this is believed to be specific depending on the nature of each activity.

ISO 9001

ISO 9001:2008 provides the requirements for quality management. To qualify, an entity must demonstrate an ability to consistently provide products that meet the needs of the customer, and adhere to applicable statutory and regulatory requirements. The entity must also demonstrate commitment to enhancing customer satisfaction, and have in place a process for continuous improvement.

AS/NZS 4801

AS/NZS 4801:2001 is an Australian/New Zealand standard for occupational health and safety management. This particular standard specifies requirements for an ‘Occupational Health and Safety (OHS)’ certificate that enables an entity to formulate policy and goals accounting for legislative requirements and information about risks and hazards.

EMAS

The Eco Management and Audit Scheme (EMAS) is a standard which encourages entities to evaluate, report and improve on their environmental performance.

Environmental performance reporting must be done through an independently verified third-party (EMAS, 2013).

OHSAS 18001

The Occupational Health and Safety Assessment Specification (OHSAS) 18001 is an international occupational health and safety specification. Key areas addressed are: planning for hazard identification; risk assessment; training, awareness and competence; operational control; performance monitoring and improvement; consultation and communication with others (BSI, 2013).

2.2.3 Scores and indices

ESG scores and indices have surfaced in the last few years and are expected to proliferate according to Chief Investment Officer of Green Alpha Advisors, Garvin Jabusch (2009). The origin of ESG indices can be traced back to the gradual movement of SRI from an ethical logic to a more activist stance beginning 1970s–1980s (Jemel-Fornetty et al., 2011). It was not until the 1990s that SRI expanded into the financial community and started flourishing within investment houses. The beginning of 2000 saw the emergence of SRI research where environmentally-focused indices were prominent and in more recent times the inclusion of ESG as part of the evaluation criteria (Jemel-Fornetty et al., 2011). This came about as a response to the timely launching of the Principles of Responsible Investment (PRI) coalition (currently over 1000 investment institutions have become signatories with over US$30 trillion worth of assets under management) in April 2006 by the United Nations Secretary General Kofi Annan in collaboration with more than 20 institutional investors. The PRI prescribes six main principles and plays the role of supporting investors by sharing best practices and facilitating collaborations (PRI, 2006).

Today, a handful of scores and indices exist in the market which attempts to measure ESG performance of companies such as KLD, EIRIS, SAM, FTSE4Good, MSCI's ESG index, Asian Sustainability Reporting (ASR), among others. Of these reporting tools, only a few actually disclose information about the criteria and methodology used behind their ESG measurements. A discussion of these major tools are summarised here for the reader.

Kinder Lydenberg Domini (KLD)

KLD evaluates a company's environmental, social and governance performance. Its scoring is designed using a binary scale where a value of '1' indicates the presence of a particular issue while '0' indicates the absence of an issue. KLD has its own independent research staff equipped with industry and issue specialties (environment; community relations; employee programs and diversity; product safety and accessibility; labour relations; human rights; and governance). The criteria assessed are divided into 'strengths' and 'concerns'. Typically, a KLD score is derived by subtracting the 'concerns' from the 'strengths' to arrive at a single net value (see Hillman and Keim, 2001).

Experts in Responsible Investment Services (EIRIS)

EIRIS functions as an independent, not-for-profit company which prides itself as a global leading provider of research into corporate environmental, social and governance criteria. It covers approximately 87 criteria including climate change, human rights, supply chain labour standards, relations with customers and suppliers, stakeholder engagement, board practices and risk management. Each item is rated on an interval scale as follows: -3 (High Negative), -2 (Medium Negative), -1 (Low Negative), 0 (Neutral), 1 (Low Positive), 2 (Medium Positive) and 3 (High Positive) (EIRIS, 2011). EIRIS provides research covering approximately 3000 companies across Europe, North America and Asia Pacific (EIRIS, 2008)

Sustainable Asset Management (SAM)

SAM rolls out a set of questionnaires which are specifically targeted at CEOs, investor relations, sustainability departments and public affairs. The scores obtained through these surveys are weighted accordingly and form the basis for the inclusion in the Dow Jones Sustainability Index (DJSI), one of the primary global indices used to track leaders in sustainability-driven companies (UNEP, 2011).

Asian Sustainability Rating (ASR)

ASR employs a proprietary set of 100 criteria surrounding sustainability and is grouped into four main categories: general, environmental, social and governance. Scoring is done by a group of experienced investment analysts in Singapore where one point is awarded for every criterion on the list. Assessments are done solely based on publicly-available information such as regulatory filings and corporate websites and the data has to be within 18 months from the period the assessment is conducted (ASR, 2011).

Dow Jones Sustainability Index (DJSI)

DJSI, first launched in 1999, is a global sustainability benchmark (DJSI, 2009). Firstly, the top 2500 companies in terms of float-adjusted market capitalisation across industries/sectors are invited to participate in a corporate sustainability assessment based on SAM's questionnaire. Companies are then filtered out as part of the DJSI construction process. The stock performance of the world's leading companies in terms of social, economic and environmental criteria (the DJSI family) is then monitored on a continuous basis. The process is shown in Figure 2.4.

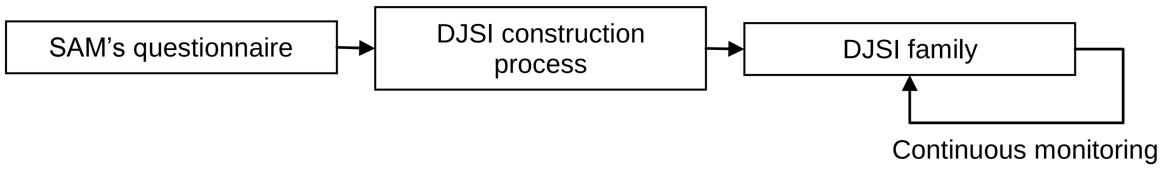


Figure 2.4 DJSI corporate sustainability assessment (DJSI, 2009).

MSCI ESG Indices

MSCI provides investment decision support tools to over 5000 clients on pension funds and hedge funds. MSCI generates scores for each applicable criterion (environmental, social and governance). These scores are then aggregated to form one composite ESG score which is mapped to a letter scale, much like the credit rating structure where AAA represents the highest sustainability performance while C represents the lowest sustainability performance (MSCI, 2011).

FTSE4Good Index

The FTSE4Good inclusion criteria was developed with similar aims as all the other tools, which is to provide investors a means by which they could identify and invest in companies that meet the minimum requirement of socially responsible practices. To be included in the FTSE4Good Index Series, companies must be able to meet bare requirements in five criteria, namely working towards environmental sustainability, upholding and supporting universal human rights, ensuring good supply chain labour standards, countering bribery and mitigating climate change. It liaises with EIRIS and other networks of international partners to research on corporate performance in ESG. Some of the research mechanisms involved are: a review of annual reports and publicly-available material; research of company websites; and sending questionnaires to selected companies (FTSE, 2011). The FTSE4Good Index series include: Global; Global 100; UK; UK 50; UK 100; Australia; Japan; and Environmental Leaders Europe 40 among others (FTSE4 Good Index Series, 2012).

Shanghai Stock Exchange (SSE)-Corporate Social Responsibility Index

The SSE-CSR index tracks the performance of the top 180 companies listed in the Shanghai Stock Exchange which have the best-in-class practices in corporate social responsibility (SSE, 2013).

Bloomberg ESG Disclosure Scores

Up to 2010, Bloomberg's research into approximately 20,000 of the most capitalised companies across 73 countries resulted in ESG data for only 3600 companies (Suzuki and Levy, 2010). Suzuki and Levy (2010) note that although the response to Bloomberg's Sustainability Survey has been disappointingly low, companies' coverage on ESG criteria have grown by approximately 11–12% annually. In an effort to encourage companies to disclose more ESG data, Bloomberg decided to score companies based on their ESG data disclosure. The Bloomberg ESG Disclosure Score out of 100 is based on GRI's guidelines. There are four types of scores, namely Environmental Disclosure Score, Social Disclosure Score, Governance Disclosure Score and ESG Disclosure Score (overall combination of Environmental, Social and Governance Disclosure Scores) (Suzuki and Levy, 2010). Weightings differ by sectors. For example, the omission of the number of fatalities would not be considered significant for a retail company but will be punitive for a company in the oil and gas sector. Eccles et al. (2011) study the market interest in Bloomberg's ESG data. They find that generally interest in both environmental and governance criteria supersedes social criterion. Some of their findings of the global market interest in Bloomberg's ESG data are summarised in Appendix E.

Trucost

Trucost creates environmental profiles of companies accounting for 464 industry sectors worldwide and monitors about 100 different types of environmental impacts (Trucost, 2013). There are four major steps in the evaluation process. The first step involves conducting a segmental analysis to identify a company's activities and accordingly assign revenues and costs to each of these activities. The second step involves creating an environmental profile depicting the company's direct and supply chain environmental impacts. The third step involves enhancing the profile developed by incorporating publicly-available sources such as annual reports and websites. Additionally, during this step, companies are invited to verify the environmental profiles created for them. In the fourth and final step, Trucost generates a report on companies' environmental impacts and makes suggestions to reduce these impacts (Trucost, 2013). Not much information about these environmental profiles is disclosed in the Trucost website although Marquis and Toffel (2012) did highlight that Trucost have developed two environmental criteria, namely an absolute disclosure ratio and a weighted disclosure ratio.

(i) Absolute disclosure ratio

'The absolute disclosure ratio is the proportion of relevant environmental criteria for which a company publicly discloses quantitative information. Trucost determines (a) the set of criteria relevant to a company based on the industries in which it operates (the denominator) and (b) the subset of those criteria that the company publicly discloses in annual reports, regulatory filings and company websites (the numerator)' (Marquis and Toffel, 2012, p. 21).

(ii) Weighted disclosure ratio

'The weighted disclosure ratio takes this concept a step further by incorporating the extent of environmental impact associated with each environmental criterion. If Company A discloses only the ten least damaging criteria out of 20 and Company B discloses only the ten most damaging criteria out of 20, they will have the same absolute disclosure ratio but very different weighted disclosure ratios, as Company A is concealing more important information ... the weighted disclosure ratio shows how much of the most important information was disclosed' (Marquis and Toffel, 2012, p. 22).

2.3 Summary of other non-formal SRTs in the corporate sector

Apart from the major SRTs discussed, there has been a growing body of research in this area (Roca and Searcy, 2012). For example, van Marrewijk and Hardjono (2003) introduce a framework to support corporate transformation towards more sustainable ways of doing business. Figge et al. (2002) present a balanced scorecard concept for sustainability management. Möller and Schaltegger (2005) promote the use of the balanced scorecard concept but with a focus on corporate environmental management. Dias-Sardinha and Reijnders (2001) suggest an evolutionary framework (dealing with strategic objectives such as compliance/pollution control, pollution prevention, eco-efficiency, eco-innovation, eco-ethics and sustainability) for evaluating environmental performance of companies. Given that most SRTs are primarily for private companies, Lundberg et al. (2009) developed a framework on environmental performance measurement (using a combination of the causal-chain framework pressure-state-response and management by objectives) specifically for Swedish public sector companies. Azzone et al. (1996) propose an integrated framework for environmental performance. In this framework, the four main criteria used are state of the environment, corporate environmental policy, environmental management and eco-balance improvement. The other contributions are summarised in Table A1.

2.4 Critique of corporate SRTs

One of the main problems with current corporate SRTs is the lack of standardisation in the criteria, terminology and methodology proposed. This gives rise to difficulty in comparing and benchmarking sustainability performance of companies. Escrig-Olmedo et al. (2010) share a similar view in their study which examines the different criteria proposed across different sustainability scoring tools. Delmas and Blass (2010) claim that some tools 'choose to focus on past or current measured performance while others put emphasis on the potential to improve future performance based on current management practices' (Delmas and Blass, 2010, p. 248). They also highlight that there is a trade-off between what can be measured and what should be measured, emphasising data availability as a concern.

Morse and Fraser (2005) criticise the Environmental Sustainability Index (ESI) for creating a misleading impression that Western countries are more sustainable than developing countries, 'over-generalising' the relative sustainability of different countries and promoting simplified conclusions on the relationship between economic growth and environmental sustainability.

Kolk et al. (2008) claim that neither the level of carbon disclosure that CDP promotes nor the more detailed carbon accounting provides valuable insights to investors, NGOs or policy makers. 'Carbon accounting is not very useful in understanding the market and technological risks and opportunities facing various companies and sectors, while voluntary carbon disclosure remains inconsistent and difficult to interpret.' (Kolk et al., 2008, p. 721).

A number of studies have critiqued the GRI framework. Moneva et al. (2006) analyse the performance criteria in GRI and conclude that there is an imbalance of emphasis between economic, social and environmental criteria. 'In this sense, it can be observed as socially biased reporting given that more than 50% are in this dimension (social)' (Moneva et al., 2006, p. 131). They add that the concept of sustainable development underlying the GRI guidelines reveals the following problems: 'runs the risk of losing sight of the big picture for sustainability (globalisation, trade); obscures the acquiring of an integrated view of business sustainability; contributes to the perception of the sustainable development concept from a reductionism approach placing the three criteria of sustainability (economic, social and environmental) at the same level and forgetting synergies between them; promotes the construction of a set of criteria instead of instilling business with values to change their mentality' (Moneva et al., 2006, p. 135). Dumay et al. (2010) share similar concerns with Moneva et al. (2006) and caution that GRI guidelines merely promote a 'managerialist' approach to sustainability and this in turn may lead companies into an 'evaluatory trap'. That is, companies are more concerned about how they perform based on the criteria rather than genuinely thinking about what they can do to further improve their efforts. Isaksson and Steimle (2009, p. 179) argue that GRI guidelines do not consider the needs of the customers sufficiently and are hence inadequate in answering pertinent questions such as 'How sustainable a company is?' or 'How quickly it is approaching sustainability?' Fonseca et al. (2012) perform 41 confidential semi-structured interviews with key informants (those who use, train, research, promote and provide services relating to sustainability assessment and reporting) and suggest the following improvements to the various aspects of the current GRI-based approach in sustainability reporting (Table 2.5).

Reporting aspects	Critique of GRI-based approach	Recommended approach
Guiding vision	• Sustainability, overlooking the need to operate within the capacity of the biosphere	• Sustainability, respecting the need to operate within the capacity of the biosphere
Conceptual framework	• Tacit, non-systemic and issues-based	• Explicit, geographically-based and scale-based
Evaluation of trade-offs	• Overlooked	• Assessed, justified and explained
Geographical scope	• Weakly addressed	• Implemented from local to global (regional/national-level and global level reports)
Temporal orientation	• Predominantly retrospective	• Includes forecasting or backcasting techniques
Type of criteria	• Non-integrated, mostly pressure and response (referring to DPSIR)	• Include integrated and non-integrated criteria, addressing pressure, state, response as well as relationships between them
Disclosures of assumptions and uncertainties	• Very limited	• Thorough

Table 2.5 Critique of GRI's framework and suggestions for improvement (Fonseca et al., 2012).

The inconsistency of sustainability reporting can be seen through a recent exploratory study on occupational health and safety (OHS) criteria by O'Neill et al. (2011). Their study reveals that different companies have a tendency to adopt a variety of definitions and units of measurement for reporting on health and safety. Table 2.6 gives a summary of the findings of O'Neill et al. (2011) based on published reports for the years 1997, 2000, 2003 and 2006.

Company	Reported criteria	Definition
Company 1	Injury duration rate (1997)	Days per lost time injury
	Lost workdays (2003)	Lost workdays per 200,000 work hours
	Lost workday rate (2006)	Lost workdays per 200,000 man hours
Company 2	Duration rate (2006)	Measures the impact of injuries on people by the number of days they are away from their unrestricted duties per injury
Company 3	LTI severity rate (2003)	Full days lost in LTIs per million work hours (where LTI is injuries resulting in being absent from work for one or more complete days or shifts)
	LTI severity rate (2006)	Injury days lost per million exposure hours
Company 4	Hours lost % (2000)	Percentage of hours through lost injury
	Hours lost % (2003)	Percentage of hours lost due to workplace injury (as a % of hours worked)
	Hours lost % (2006)	Undefined
Company 5	Weighted average injury severity (2000)	Undefined
	Severity rate (2006)	Lost workday frequency rate plus the restricted workday frequency rate (days lost or with restricted duties because of a recordable case) per 200,000 hours worked (however, the graph for the data is titled: Lost workday case frequency rate (frequency per 200,000 hours worked)
	Total days lost or restricted due to workplace injuries (2006)	
Company 6	Injury severity (2000)	Average working days lost per employee
	Injury severity (2003)	Hours lost per million hours worked
Company 7	Injury days lost (2000)	Not defined (but appears to be: total number of days lost to injury)
	Lost time injury severity rate (2000)	Days lost to injury per million hours worked
Company 8	Days lost to injury (2006)	Rate of days lost to injuries and restricted duty
Company 9	Injury severity (2006)	Undefined
Company 10	Serious personal injury (1997, 2000, 2003)	Undefined
	Prescribed incapacity (1997, 2000, 2003)	

Table 2.6 Summary of health and safety criteria disclosed (O'Neill et al., 2011) (LTI = lost time due to injuries).

A study of 10 sustainability reports of Australian companies that have voluntarily participated in the Carbon Disclosure Project (CDP) reveals that there are differences in the reporting of greenhouse gas emissions, particularly with regard to the reporting time frame used, namely the fiscal year or the calendar year, the units used and the nature of information disclosed, as shown in Table 2.7.

Company	Time frame	Units	Nature of information disclosed
Company 11	2007, 2008, 2009, 2010	Million tonnes CO_2-e	Distinction made in reporting of scope 1 and 2 emissions
Company 12	2007, 2008, 2009, 2010	Million tonnes CO_2-e	Report on scope 1 and 2 emissions, indicating corrections from previous years as well.
Company 13	2007/2008, 2008/2009	Tonnes CO_2-e	Distinction made in emissions based on different sources (diesel, electricity, petrol and gas)
Company 14	2007/2008, 2008/2009, 2009/2010	Kilotonnes CO_2-e	Distinction made in reporting of scope 1 and 2 emissions.
Company 15	2008, 2009, 2010	Tonnes CO_2-e/tonne of production	Emissions of total carbon dioxide equivalent per tonne of production
Company 16	2007/2008, 2008/2009, 2009/2010, Target 2010/2011	Tonnes CO_2-e/MWH	Carbon intensity of operated generation portfolio.
Company 17	2007, 2008, 2009, 2010	Tonnes CO_2-e	Distinction made in reporting of scope 1 and 2 emissions.
Company 18	2009, 2010, 2011	Tonnes CO_2-e and Tonnes CO_2-e/FTE	Gross emissions, additional emissions, and gross emissions per FTE
Company 19	2007, 2008, 2009, 2010	Tonnes CO_2-e/FTE	Carbon emissions per FTE
Company 20	2008, 2009, 2010	Tonnes CO_2-e	No clear distinction of scope 1 and 2 emissions.

Table 2.7 Differences in company reporting on greenhouse gas emissions. Carbon dioxide equivalent (CO_2-e) is defined as a measure used to compare between greenhouse gas emissions depending on their global warming potential over 100 years. Full-time equivalent (FTE) is defined as a unit which measures the workload of an equivalent full-time worker.

Amaeshi and Grayson (2008) conducted a study where 82 sustainability reports from accounting firms, investor associations, business coalitions, investment banks, multinational institutions, consultancies, think tanks and governments were sent to 36 experts to identify issues involved in integrating ESG risks. The first phase of the project found that quality of data and materiality of ESG risks were ranked at the top of the list of challenges. The second phase of the project found ESG issues to be highly complex and uncertain. Language confusion was also a problem highlighted by the respondents.

According to some academic scholars (Bruno, 1997; Milne and Patten, 2002), much of corporate sustainability reporting can be viewed as a tool to hide actual practices. An anticipated flow-on effect to this is the failure of ESG assessments relying on such reporting to truly distinguish the leaders from the laggards.

A number of publications (Laufer, 2003; Quirola and Schulp, 2001; Bruno, 1997; Beder, 1998; Walker and Wan, 2011; Roberts and Koeplin, 2007; Ramus and Montiel, 2005) also highlight the problem of ‘greenwashing’, which is a term used to describe a strategy that companies adopt when communicating with stakeholders on environmental issues without really addressing the issues (Walker and Wan, 2011). Beder (1998) identifies a few characteristics of companies involved in ‘greenwashing’: a company may deliberately undermine the severity of the problem, disclose or publish wildly exaggerated claims or even acknowledge environmental problems but question the availability of a solution that would help with addressing them. Anecdotal evidence suggests that unsubstantiated environmental and social disclosures may be more attributed to managing public relations rather than addressing corporate responsibility (Deegan et al., 2002; O’Donovan, 2002; Brown and Deegan, 1998; Deegan and Gordon, 1996; Hooks et al., 2002; Adams, 2002).

Similar to SRTs in the building/infrastructure sector, development in this area has not progressed to account for uncertainty in the assessment of sustainability performance (see Table B1, Appendix B). Hyde et al. (2004) show that incorporating uncertainty into multi-criteria decision making in water resource management influences the ranking of alternatives. Likewise, ignoring uncertainty in assessing companies’ sustainability performance may have an impact on the ranking of companies and ultimately their inclusion in sustainability indices. Hence, a more robust framework accounting for uncertainty in the assessment of sustainability performance is needed.

2.5 Conclusion

This chapter provides an overview of the criteria and methodology proposed by various corporate SRTs. Corporate SRTs can be divided into the following: frameworks (principles and initiatives); standards; as well as scores and indices. As discussed, some of the existing deficiencies with SRTs include the lack of standardisation which makes comparability difficult, companies using SRTs to hide their actual practices, companies deliberately manipulating stakeholders' perceptions through 'greenwashing' and the lack of attention to uncertainty in the assessment of sustainability performance.

CHAPTER 3 – A REVIEW OF BUILDING/INFRASTRUCTURE SUSTAINABILITY REPORTING TOOLS (SRTs)

3.1 Introduction

The World Economic Forum (2011, p. 11) identifies the building sector as an area, that needs to be addressed, accounting as it does for '40% of the world's energy use, 40% of carbon output and consuming one-fifth of available water'. The large use of electricity in buildings has been identified as one of the main culprits for high emissions across the globe. The Centre for International Economics Canberra and Sydney (2007) reports that 23% of the total greenhouse gas emissions in Australia come from the energy demand of the building sector, while the US Green Building Council (USGBC, 2011) claims that both residential and commercial buildings account for 39% of total emissions in the United States, and more than any other country in the world except China.

The increased recognition that buildings are substantial carbon dioxide emitters (Reed et al., 2009), and contribute significantly to climate change, puts pressure on construction industry practitioners to incorporate sustainability goals aside from the traditional project goals of cost, time and quality (Fernández-Sánchez and Rodríguez-López, 2010). Translating sustainability goals into action at the project level is exacerbated by the individual characteristics of countries, their cultures, climates and types of buildings (Ugwu and Haupt, 2007).

As a result of a widely recognised need to identify models, metrics and tools that would help articulate the extent to which current activities are either sustainable or not sustainable (Singh et al., 2009), SRTs in the building/infrastructure sector have risen in popularity. Infrastructure includes transport (roads and bridges, bus and cycle ways, footpaths, railways), water (sewage and drainage, water storage and supply), energy (transmission and distribution) and communication (transmission and distribution), among others (AGIC, 2012).

While Chapter 2 provides background information on corporate SRTs, this particular chapter focuses on providing a review of available tools used to assess and report sustainability in the infrastructure and building sectors. The tools are commonly used in their country of origin, particularly if this is legislated, but are also adopted in other countries.

The structure of the chapter is as follows. The following three sections explore, respectively, the nature of major building SRTs, infrastructure SRTs and life cycle tools applicable to both buildings and infrastructure. Next, a critique of these tools and conclusions from the review are discussed.

This chapter acknowledges that the multiplicity of terms in SRTs can be confusing to the reader. As such, it is important to clarify some of this terminology upfront. Typically, for most SRTs, there are levels of hierarchy in the list of sustainability criteria proposed. To ensure consistency, the top (highest) level of this hierarchy will be referred to as 'criteria', and the next (lower) level as 'subcriteria'.

3.2 SRTs for buildings

A review of some of the major tools applicable to buildings is given. This is followed, after a similar review for infrastructure and life cycle tools, by a critique.

BREEAM

Building Research Establishment's Environmental Assessment Method (BREEAM), established in 1990, was first launched in the UK with office buildings in mind (Bonham-Carter, 2010; Sharifi and Murayama, 2013), but later expanded in scope to also include specific schemes for residential housing and neighbourhoods. It is perceived to be one of the world's foremost environmental reporting tools for buildings (Crawley and Aho, 1999). Scores are awarded to 10 criteria – management, health and well-being, energy, transport, water, materials, waste, land use and ecology, pollution and innovation – according to performance, and summed to produce an overall score.

This score is then matched to an award: Pass, Good, Very Good, Excellent or Outstanding.

Table 3.1 highlights both the criteria and subcriteria in BREEAM. Scores are awarded upon meeting the agreed performance targets for each of the subcriteria.

Management • Commissioning • Construction site impacts • Security	**Waste** • Construction waste • Recycled aggregates • Recycling facilities
Health and well-being • Daylight • Occupant thermal comfort • Acoustics • Indoor air and water quality • Lighting	**Pollution** • Refrigerant use and leakage • Flood risk • NO_x emissions • Watercourse pollution • External light and noise pollution
Energy • CO_2 emissions • Low or zero carbon technologies • Energy sub-metering • Energy efficient building tools	**Land use and ecology** • Site selection • Protection of ecological features • Mitigation/enhancement of ecological value
Transport • Public transport network connectivity • Pedestrian and cyclist facilities • Access to amenities • Travel plans and information	**Materials** • Embodied life cycle impact of materials • Materials re-use • Responsible sourcing • Designing for robustness
Water • Water consumption • Leak detection • Water re-use and recycling	**Innovation** • New design and construction methods not formally recognised

Table 3.1 BREEAM criteria and subcriteria (BREEAM, 2012).

The award benchmarks for new buildings, refurbishments and, where applicable, fit-out projects, are presented in Table 3.2. The BREEAM tool offers a set of weightings to be taken into account as part of the assessment process (see Table 3.3) (BREEAM, 2012).

Award	**Score (%)**
Unclassified	< 30
Pass	≥ 30
Good	≥ 45
Very Good	≥ 55
Excellent	≥ 70
Outstanding	≥ 85

Table 3.2 BREEAM award (BREEAM, 2012).

BREEAM criterion	**Weightings (%)**	
	New builds, extensions and major refurbishments	**Building-fit-out only (where applicable to scheme)**
Management	12	13
Health and well-being	15	17
Energy	19	21
Transport	8	9
Water	6	7
Materials	12.5	14
Waste	7.5	8
Land use and ecology	10	N/A
Pollution	10	11
Innovation	10	10

Table 3.3 BREEAM's criteria weightings (BREEAM, 2012).

LEED

Leadership in Energy and Environmental Design (LEED) was developed by the US Green Building Council (USGBC) in 2000. Since its inception, LEED has grown to encompass more than 14,000 projects in the US and more than 30 countries (Nguyen and Altan, 2011). This tool promotes sustainable building and development practices through a suite of reporting, and recognises projects which are committed to better environmental and health performance (LEED, 2012). Two major building typologies covered by LEED are:

1. New Construction and Major Renovations v2009. The criteria and scores (included in parentheses) available for each criterion are as follows: sustainable sites (26), water

efficiency (10), energy and atmosphere (35), indoor environmental quality (15), innovation in design (6), regional priority (4) as well as materials and resources (14) (LEED, 2009a).

2. Existing Buildings: Operations and Maintenance v2009. The criteria and scores (included in parentheses) available for each criterion are as follows: sustainable sites (26), water efficiency (14), energy and atmosphere (35), indoor environmental quality (15), innovation in design (6), regional priority (4) as well as materials and resources (10) (LEED, 2009b).

Note that the description (with unspecified building typology) provided by Berardi (2012, p. 416) is for New Construction and Major Renovations v2. For both typologies (New Construction and Major Renovations v2009 and Existing Buildings: Operations and Maintenance v2009), scores are accumulated using a base of 100 (innovation in design and regional priority are added separately), and rated according to a scale as shown in Table 3.4. There are embedded prerequisites within each criterion (except for sustainable sites - Existing Buildings: Operations and Maintenance v2009) which must be met before a score is awarded. LEED for Neighbourhood Development (2009) is the latest USGBC reporting tool, which incorporates site selection, design and construction elements (Hurley and Horne, 2006), taking into account both landscape and regional contexts (Sharifi and Murayama, 2013).

Award	**Score**
Certified	40–49
Silver	50–59
Gold	60–79
Platinum	80 and above

Table 3.4 LEED award (LEED, 2012).

Green Star

Green Star, developed by the Green Building Council of Australia (GBCA), is a comprehensive voluntary building SRT used in Australia. It was initially developed to accommodate the need for buildings operating in hot climatic areas (Roderick et al., 2009; Tronchin and Fabbri, 2008). It incorporates ideas from other tools, such as

BREEAM and LEED, and other environmental criteria specific to the Australian environment (Lockwood, 2006). Green Star covers the nine criteria shown in Table 3.5, where scores are awarded if targets are met:

Green Star criterion	Purpose
Management	Scores address the adoption of sustainable development principles from project conception through design, construction, commissioning, tuning and operation.
Energy	Scores target reduction of greenhouse emissions from building operation by addressing energy demand reduction, use efficiency, and generation from alternative sources.
Water	Scores address reduction of potable water through efficient design of building services, water reuse and substitution with other water sources (specifically rainwater).
Land use and ecology	Scores address a project's impact on its immediate ecosystem, by discouraging degradation and encouraging restoration of flora and fauna.
Indoor environment quality (IEQ)	Scores target environmental impact along with occupant wellbeing and performance by addressing heating, ventilation and air conditioning (HVAC), lighting, occupant comfort and pollutants.
Transport	Scores reward the reduction of demand for individual cars by both discouraging car commuting and encouraging use of alternative transportation.
Materials	Scores target resource consumption through material selection, reuse initiatives and efficient management practices.
Emissions	Scores address source of pollution from buildings and building services to the atmosphere, watercourse, and local ecosystems.
Innovation	Green Star seeks to reward marketplace innovation that fosters the industry's transition to sustainable building.

Table 3.5 Green Star criteria (GBCA, 2012b).

Weightings for the criteria are available in Green Star. These weightings are derived from (GBCA, 2012b):

- The OECD Sustainable Buildings Report Project.
- Australian Greenhouse Office.
- CSIRO (Commonwealth Scientific and Industrial research Organisation).
- Commonwealth Department of Environment and Heritage.
- A National Survey conducted by the Green Building Council.

A single, overall score is calculated based on a series of steps shown in Figure 3.1. First, for each criterion, a score is determined. Then, weightings are applied. All the weighted criteria scores are summed. Innovation points can be obtained by either engaging with innovative strategies and technologies or exceeding the Green Star benchmark. Innovation points are added to the weighted criteria scores. This gives an overall score, which is then matched to an award (see Table 3.6). The Green Building Council of Australia only certifies buildings with 4, 5, or 6 Green Stars.

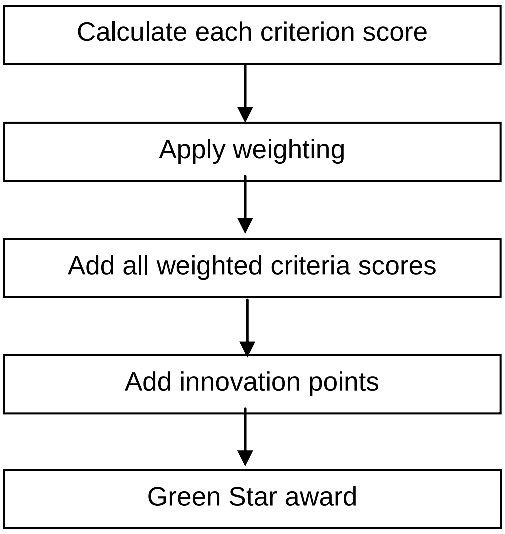


Figure 3.1. Methodology for Green Star award (GBCA, 2012b).

Award	Score	Description
1 Star	10–19	Minimum practice
2 Star	20–29	Average practice
3 Star	30–44	Good practice
4 Star	45–59	Best practice
5 Star	60–74	Australian excellence
6 Star	≥ 75	World leadership

Table 3.6 Green Star awards (GBCA, 2012b; Roderick et al., 2009; Mitchell, 2010).

CASBEE

The Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) was introduced by the Japan Sustainable Building Consortium in 2002 to promote the concept of sustainable buildings in Japan (Sev, 2011). CASBEE defines sustainable buildings as those that are designed to save energy and resources, recycle materials, reduce emissions of toxic substances to the environment, harmonise the local climate, traditions and culture, and lastly to sustain and improve the quality of human life while maintaining the capacity of the ecosystem at both local and global levels (CASBEE, 2002).

The CASBEE tool is based on three premises: it is designed for the assessment of buildings corresponding to their lifecycle; it makes a clear distinction between environmental load (L) and building performance (Q), where items in each are scored using five progressive levels 1 to 5; it applies the concept of eco-efficiency where Building Environmental Efficiency, BEE = Q/L. BEE represents the overall environmental performance of a building, Q incorporates quality (consisting of combined scores of various subcriteria, such as indoor environment, quality of services, and outdoor environment on site), and L incorporates energy, resources and materials, and off-site environment (CASBEE, 2002).

The BEE graph (Figure 3.2) shows that the higher the Q value and the lower the L value, the more sustainable the building is. Ordinary buildings are represented by a gradient of BEE = 1.0. Depending on which region in Figure 3.2 that BEE falls into, a different CASBEE award is available; C (poor), B- (Fairly poor), B+ (Good), A (Very good) and S (Excellent). In 2008, CASBEE included the consideration of global warming by estimating lifecycle CO_2 emissions as part of its off-site environment subcriterion (Sharifi and Murayama, 2013). More recently, Murakami et al. (2011) have worked on further developing the CASBEE tool for city assessment.

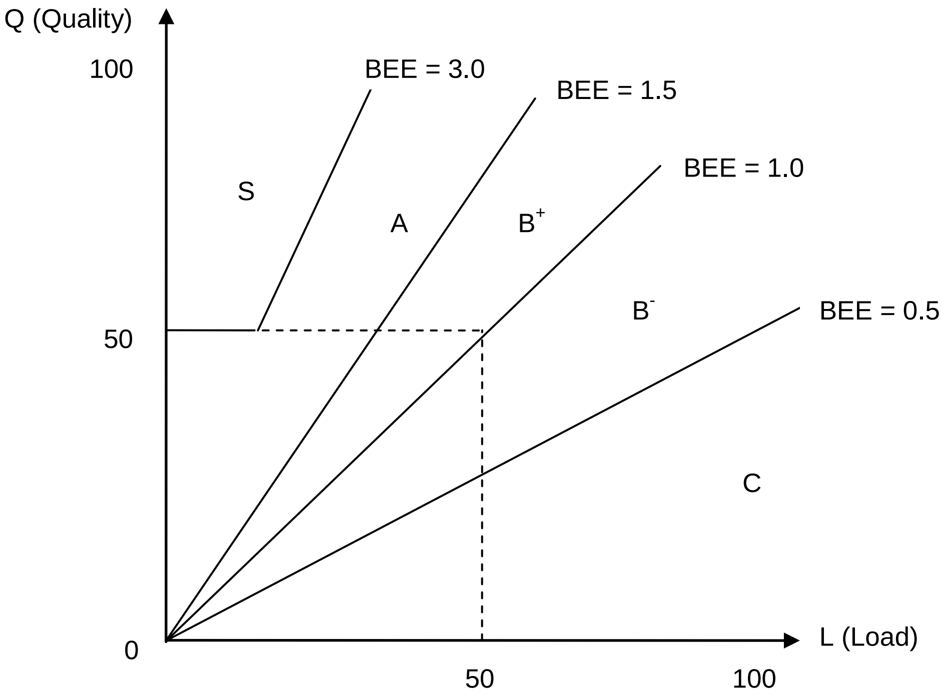


Figure 3.2 The BEE graph (CASBEE, 2002).

HK-BEAM

The Hong Kong Building Environmental Assessment Method (HK-BEAM) was introduced in 1996 by the Hong Kong BEAM Society, a not-for-profit organisation consisting of professionals within the building industry (Chan and Chu, 2010). It began primarily as a voluntary environmental reporting tool for high-rise buildings, and subsequently branched out into two main categories covering all local buildings: the HK-BEAM Version 4/04 for New Buildings (for planning, design, construction, commissioning, with design and specifications for deconstruction) and the HK-BEAM Version 5/04 for Existing Buildings (for management, operation, and maintenance) (Lee et al., 2007; Chan and Chu, 2010). From January 2013, HK-BEAM Plus v1.2 became mandatory.

HK-BEAM is comparable to other SRTs. The criteria (scores+bonus points) are as follows: site aspects (18+1 bonus point); material aspects (11+2 bonus points); energy aspects (39+2 bonus points); water aspects (7+2 bonus points); indoor environmental quality (30+3 bonus points) and innovative techniques (1+5 bonus points) (HKGBC and BEAM Society, 2012). The tool suggests weightings for these criteria, as shown in

Table 3.7. These weightings differ depending on whether it is an existing or new building.

Criterion	Weighting (%) Existing buildings	Weighting (%) New buildings
Site Aspects (SA)	18	25
Material Aspects (MA)	12	8
Energy Use (EU)	30	35
Water Use (WU)	15	12
Indoor Environmental Quality (IEQ)	25	20

Table 3.7 HK-BEAM criteria weightings (HKGBC and BEAM Society, 2012).

Similar to BREEAM, the determination of an overall assessment grade is by percentage of applicable scores obtained under each criterion, including its weighting factor. SA, EU and IEQ are perceived to be important and therefore a minimum percentage must be obtained in these criteria to qualify for an overall grade (see Table 3.8). The overall grade (%) achieved is mapped to an award (Table 3.8).

Award	Overall (%)	SA (%)	EU (%)	IEQ (%)
Platinum	75	70	70	70
Gold	65	60	60	60
Silver	55	50	50	50
Bronze	40	40	40	40

Table 3.8 HK-BEAM awards (HKGBC and BEAM Society, 2012).

Building actual performance

While most SRTs (for example, Green Star) focus on the potential of environmental impact during the design phase (design performance), some tools inform on actual building performance. Typically, assessments of actual building performance are conducted on an annual basis (NABERS, 2011). Two examples are the National Australian Built Environmental Ratings Scheme (NABERS) and Energy STAR which are reviewed here.

NABERS

NABERS, launched in 1998 in Australia, informs on the actual environmental performance of buildings, tenancies and homes. Criteria that are assessed include water usage, energy usage, waste and indoor environment. There are currently four types of reporting tools available for offices, shopping centres, hotels and homes (NABERS, 2011). The awards range from 1 (worst) to 5 (best) to reflect on the point-in-time annual performance of buildings (with reference to data from 12 months occupation/use). For office buildings, there is a subdivision into tenancy, base building and whole building, as shown in Table 3.9. The tenancy subdivision covers only tenanted space and is applicable to tenants occupying either a leased or privately owned space within a commercial building. For building owners and property managers, two subdivisions are applicable: base building which focuses on central building services and common areas; and whole building which covers tenanted space, central building services and common areas (NABERS, 2011).

Office building subdivision	**Coverage**
Tenancy	Tenanted space
Base building	Central building services and common areas
Whole building	A combination of the above

Table 3.9 NABERS - office buildings (NABERS, 2011).

Mitchell (2010) describes the assessment process in relation to NABERS' energy criterion. The first step involves converting energy use into greenhouse gas equivalents. This is done with reference to the emissions intensity of the standard energy mix across the relevant state/territory of Australia. For example, if the building was located in Victoria it will have its emissions relating to electricity calculated based on the fact that in Victoria most electricity comes from high emitting brown-coal-fired power stations. The raw emissions figures are then 'normalised' by taking into consideration the hours of use of the premises, the occupant and equipment density and local climate. These normalised figures are then divided by the area assessed, giving a figure expressed in terms of emissions per square metre. Finally, this figure is compared against the benchmark for the relevant state/territory and type of building to determine a suitable award for it. An example of a NABERS award for a base building using normalised emissions per square metre is shown in Table 3.10. The normalisation and benchmarking process is reviewed periodically. Median performance, described in terms of half stars, is allowed.

Award	**Emissions (kg CO_2 /m^2)**	**Comments**
1 star	199	Poor – poor energy management
2 star	167	Average building performance
3 star	135	Very good – current market best practice
4 star	103	Excellent – strong performance
5 star	71	Exceptional – best building performance

Table 3.10. NABERS award (Mitchell, 2010).

Confusion may exist between Green Star and NABERS because these awards are quite similar in nature (Mitchell, 2010). The differences between Green Star and NABERS are summarised in Table 3.11.

Item	Green Star	NABERS
Environmental Impact Assessment	• Potential	• Actual
Scope	• Design	• Performance
Phase	• Design phase	• In operation/use
Owner	• GBCA	• Department of Environment, Climate Change and Water NSW
Coverage	• Office • Retail • Healthcare • Education • Industrial	• Office • Homes • Hotel • Shopping centres
Certifiable awards	• 4,5, or 6 stars	• 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, or 5 stars
Legislation	• Accreditation is on a voluntary basis	• NABERS Energy rating must be disclosed when leasing or selling

Table 3.11 Differences between Green Star and NABERS.

Energy STAR

Energy STAR derives from the US Environmental Protection Agency and the US Department of Energy. Essentially, it is a tool used to track and benchmark a building's energy performance. The energy performance scale is developed based on five steps (Energy STAR, 2011):

- Identification of the best available survey data representative of buildings nationwide, differentiated by size, energy use and operation. One such example is the US Department of Energy's Commercial Building Energy Consumption Survey (CBECS) conducted once every four years. (See EIA, 2012.)
- Assessment of the characteristics of buildings surveyed, via a statistical analysis.

- From the results of the statistical analysis, development of a model to predict the energy use of a certain type of building accounting for its location and type of operation.
- For each surveyed building, calculation of an energy efficiency ratio (actual to predicted energy use).
- Use of the energy efficiency ratio to create a distribution of energy performance for the population of buildings. This forms the Energy STAR performance scale from 1 to 100 where a score of 50 means that the building is at an average level.

3.3 SRTs for infrastructure

A review of some of the major tools applicable to infrastructure is given. This is followed by a critique.

ASPIRE

A Sustainability Poverty Infrastructure Routine for Evaluation (ASPIRE) was developed by ARUP and Engineers Against Poverty (EAP) to add value for a range of stakeholders committed to the development of sustainable pro-poor infrastructure (Gryc, 2012); it informs on poverty reduction performance of infrastructure projects. It considers four major criteria - the environment, society, economics and institutions - with breakdowns of four to six subcriteria under each criterion as depicted in Figure 3.3.

The primary consideration for the environment is in terms of how it reduces impact on natural resources such as air, land, water, biodiversity and materials. Infrastructure is assessed in terms of how well it meets society's needs equitably and how it reduces poverty via public health, culture and accessibility to services. Project viability, macroeconomic effects, livelihood opportunity and the creation of an equitable economy are considered. The criterion of institution encompasses four subcriteria, namely policy, governance, skills and reporting; these represent the capacity and effectiveness of the institutional environment in supporting the delivery of the infrastructure (Gryc, 2012). The assessments are done based on scoring, where the user goes through a series of questions and is provided with illustrations of best to worst case scenarios to help in the allocation of non-weighted scores. The aggregated scores for each criterion are then represented using a traffic light idea where green indicates strength and red indicates weakness.

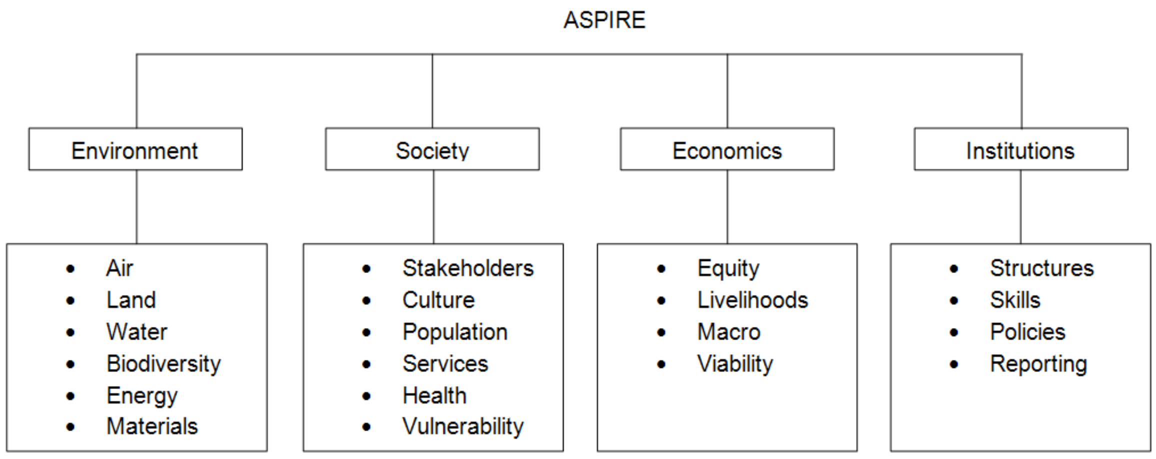


Figure 3.3. ASPIRE's framework (Gryc, 2012).

AGIC

The Australian Green Infrastructure Council (AGIC) officially released its Infrastructure Sustainability Rating Tool v1.0 in December 2012. Compared to the majority of the SRTs, AGIC adopts a much broader range of criteria, and this includes management; procurement and purchasing; climate change adaptation; energy; water; material; discharges to air; land and water; land; waste; ecology; health; heritage; stakeholder participation; urban design; and innovation. There are three types of reporting under AGIC, summarised in Table 3.12, and the level of sustainability of an infrastructure project is scored on a 100-point scale (see Table 3.13).

Types of reporting	When can this be applied?	Description
Design	End of planning and design	• Awarded based on the inclusion of design elements and construction requirements.
As-built	End of construction	• Includes measured sustainability performance during construction and built into the infrastructure asset.
Operation	During operation	• Given after 24 months of operation. Based on the measured 'green' performance of operating infrastructure.

Table 3.12 AGIC's three reporting types (AGIC, 2012).

Award	Score
Not eligible	< 25
Commended	25 to < 50
Excellent	50 to < 75
Leading	75 to 100

Table 3.13 AGIC's award (AGIC, 2012).

Non-formal SRTs

Publications to date, on infrastructure projects, have focussed on the development of sustainability criteria. For example, Fernández-Sánchez and Rodríguez-López (2010) recommend more than 80 criteria for infrastructure projects in Spain. From their study, they find that 11 of the criteria voted for by stakeholders in the top 30 (based on the Analytic Hierarchy Process) largely involve economic and social issues. These criteria (with relative importance as a percentage in parentheses) include health and safety (3.85%), necessity of work/urgency of work (3.77%), life cycle cost (3.72%), economical cost/economical benefit (3.24%), project declaration of general interest (2.96%), public participation and control on the project (2.59%), barrier effect of the project (2.38%), project governance and strategic management (2.26%), accessibility for human biodiversity (2.26), respect for local customs (2.05%) and increase in economic value (1.42%). Shen et al. (2007) suggest a sustainability project performance checklist across a project's life cycle - inception, design, construction, operation and demolition. Ugwu and Haupt (2007) identify key performance indicators

(KPIs) and assessment methods for infrastructure sustainability from a South African construction industry perspective. Sahely et al. (2005) propose sustainability criteria for urban infrastructure focusing on key interactions and feedback mechanisms between infrastructure and wider environmental, social and economic concerns. Morrissey et al. (2012) develop Strategic Project Appraisal (SPA), built on a theory of Strategic Environmental Assessment (SEA), to critically appraise project impacts from an ecological limits sense. SPA is centred on five key questions: 1) What are the potential direct and indirect key outcomes of the urban infrastructure? 2) How do these outcomes interact with the environment? 3) What is the scope and nature of these interactions with the environment? 4) How can the proposed urban infrastructure be optimally integrated with existing urban infrastructure? and 5) What is the overall effect of the proposed urban infrastructure after mitigation and adaptation strategies have been adopted?

Life cycle tools for building/infrastructure

Berardi (2012, p. 414) defines life cycle tools as those that 'measure the impact of building on the environment by assessing the emission of one or more chemical substances related to the building construction and operation'. Some of these major life cycle tools include life cycle analysis (LCA), input-output (IO) analysis and material flow accounting.

Life Cycle Analysis (LCA)

In LCA, a building is divided into activities and raw materials so that the environmental impact over a life cycle (manufacturing, transporting, deconstruction and recycling) can be assessed. The four phases in LCA are goal and scope, life cycle inventory, life cycle impact assessment and improvement (Hsu, 2010).

The first phase involves setting a goal and scope for the project. For example, a researcher may wish to investigate which structural design has a lesser environmental impact or how a structure can be further improved to lessen its impact on the environment. This should be done taking into account the target audience which could be clients from a company, government bodies or the general public. The functional unit defined as the unit being analysed throughout the steps of LCA is determined at this phase. The second phase is life cycle inventory which involves collecting and modelling of data. Data is transformed into a flowchart comprising of both inflows and outflows. Because data quality relies entirely on available information about a product, ideally cross-checking with different sources should be done. The third phase is life cycle impact. This phase involves selecting, classifying and characterising the impact on the environment using the numbers and figures derived from phase two. The final phase in LCA is improvement which involves an iteration of the aforementioned phases. This is necessary to 'identify the most important aspects of impact assessment, check the validity of results and redo aspects of the LCA that need more work' (Hsu, 2010, p. 15)

Mroueh et al. (2001) extend the LCA method for road and earth constructions. This methodology focuses on comparing industrial by-products and natural aggregates. Mithraratne and Vale (2004) develop a LCA model for New Zealand houses which takes into account embodied and operating energy requirements as well as life cycle cost over the useful life of the building. Many countries have also developed specific LCA tools; for example, BEES in the US, BOUSTEAD and ENVEST in England, Ecoinvent in Switzerland and GaBi in Germany (see Appendix F).

Input-Output (IO) Analysis

Although traditionally IO analysis has been applied to macroeconomic study of monetary flows across various sectors, it has recently gained prominence in the area of environmental impact analysis (Piluso et al., 2008). The IO tables (see Xu et al., 2010) consist of rows and columns. The rows represent outputs while columns represent inputs. From the IO table, the matrix of IO coefficients can be derived. These IO coefficients (also known as technical coefficients) represent the amount of input required to produce one unit of output (see Xu et al., 2010, for mathematical formulation). For sustainability analysis, typically a simplified IO matrix is adopted (Xu et al., 2010; Piluso et al., 2008) and the technical coefficients could potentially help answer questions such as how much carbon dioxide has been emitted for the production of one unit of steel (see Born, 1996). Extensive research has been conducted using IO analysis. For example, Norman et al. (2006) use a combination of both IO and LCA to estimate the energy use and greenhouse gas emissions associated with the manufacture of construction materials for infrastructure, building operations and transportation (public automobiles and public transit) for high and low residential densities. Pietroforte and Gregori (2003) present results of an IO analysis of the construction sector in highly developed economies (Australia, Canada, Denmark, France, Germany, Netherlands, Japan and the US). They find that the construction sector in France and Australia has a small propulsive role but a large impact in Denmark and Germany.

Material Flow Accounting

Material flow accounting describes the relationship between the economy and the environment, where 'the economy is an embedded subsystem of the environment and similar to living beings - dependent on the constant throughput of materials and energy. Raw materials, air and energy are extracted from the natural systems as inputs, transformed into products and finally re-transferred to the natural system as outputs (waste and emissions)' (Hinterberger et al., 2003, p. 2). MFA applies the law of the conservation of mass which states that total inputs must by definition equal total outputs plus any net accumulation (see EUROSTAT, 2001). EUROSTAT (2001) suggests making a distinction between material flows: direct versus indirect; used versus unused; domestic versus rest of the world (see EUROSTAT 2001, p. 20–24 for definitions and explanation of concepts in detail). Huang and Tsu (2003) conduct a material flow analysis of Taipei's urban construction. They find that the consumption of sand and gravel is about 90% of total construction material used.

Pavement Life Cycle Assessment Tool for Environmental and Economic Effects (PaLATE)

PaLATE is an Excel-based tool used in the assessment of environmental and economic impacts for pavements and roads. This tool first requires inputs such as the design, cost for a roadway, initial construction materials, transportation information (both mode and distances) as well as maintenance and equipment use. Output is generated in the form of environmental effects and associated costs. Among some of the environmental effects covered under PaLATE are energy consumption, CO_2 emissions, NO_x emissions, PM_{10} emissions, CO emissions and leachate information (Horvarth et al., 2007)

Life Cycle Analyzer

Life Cycle Analyzer is a software developed specifically to analyse the entire life cycle of concrete in all types of production be it ready-mix or prefabrication. It allows calculation of both environmental and cost impact of different mix designs. The output from this software can be used as inputs into major building SRTs such as BREEAM and LEED (BASF, 2012).

3.4 Benefits of engaging with SRTs

Several studies have highlighted the positive impact of engaging with building/infrastructure SRTs. Lee and Guerin (2010) find that LEED-certified buildings yielded positive benefits in relation to employee job performance. Miller et al. (2008) address the question on the benefits of investing in energy savings and environmental design. In their study, they use US-based Energy STAR office buildings as one set of 'green' buildings, together with LEED-certified buildings as an alternative, with large samples of non-Energy STAR and non-LEED-rated buildings included in the analysis. They conclude that going 'green' does pay off with significant rental rate differentials. Similar conclusions are found across other studies such as Fuerst and McAllister (2008), who compare rentals for LEED and non-LEED buildings, and Eichholtz et al. (2009), who compare rentals for 'green' and non-'green' buildings.

Wiley et al. (2010) conducted an empirical study to test the relationship between energy-efficient design and leasing markets for commercial real estate, and found that 'green' buildings have more superior rents and occupancy rate. Fuerst (2009) finds no trend reversal due to the economic downturn for both LEED- and Energy STAR-certified buildings, but instead argues that growth for this market segment is likely. Research focusing on the financial performance of 'green' office buildings in Australia finds that a 5-Star NABERS energy rated building delivers a higher premium value compared to a 3- to 4.5-Star NABERS energy rated building. Newell et al. (2011) find that Green Star certified buildings show a 'green' premium value. Hes (2007) justifies the effectiveness of SRTs using nine measures: reduction in environmental impact;

positive social impact; positive effect on occupant comfort; positive effect on productivity; cost savings, ease of use, rating and modelling accuracy; ability to be dynamic and support continuous improvement; and ability to support innovation in design.

3.5 Critique of building/infrastructure SRTs

In recent years, there has been some critique published of SRTs. Nguyen and Altan (2011) compare several attributes of five building SRTs by scoring them based on popularity and influence, availability, user-friendliness, applicability, data collecting process, development, and results presentation. The outcomes of their assessment (Table 3.14) show that BREEAM and LEED are better in terms of applicability and popularity. CASBEE, on the other hand, gives the highest methodology score, possibly due to its rigorous nature.

Attribute	BREEAM	LEED	CASBEE	Green Star	HK-BEAM
Popularity (/10)	10	10	6	5	5
Availability (/10)	7	7	7	8	8
Methodology (/15)	11	10	13	9	11
Applicability(/20)	13	13	11.5	10	9
Data-collecting process (/10)	7	7	6	9	8
Accuracy (/10)	8	7	9	5	5
User-friendliness (/10)	8	10	6	8	8
Development (/10)	8	8	7	8	8
Presentation (/5)	3	3	4	3	4
Final score (/100)	75	75	69.5	65	66

Table 3.14 Overall score of reporting tools (Nguyen and Altan, 2011).

Although major building SRTs (BREEAM, LEED, HK-BEAM inter alia) have been criticised in the past for the lack of attention on life cycle perspective (for example, Bowyer et al. (2006) claim that there is no requirement for consideration of life cycle inventory data in LEED; Scheuer and Keoleian (2002) find LEED to be an unreliable sustainability assessment tool when assessed from a life cycle perspective), it is interesting to note that a majority of them have started or are in the process of incorporating life cycle thinking.

Other concerns regarding SRTs have been raised. Baird (2009) argues for the inclusion of user performance criteria in such tools, claiming that buildings which perform poorly from a user's point of view are unlikely to be sustainable. Chew and Das (2007, p. 10) highlight that one of the issues with SRTs is that 'scores are lost for credits that are beyond the scope of a project. For example, sustainable site development or provisions related to fuel-efficient vehicles are not feasible in the case of a commercial building on a tight site, downtown with a well-established public transport system.' Fard (2012) and Fenner and Ryce (2008) argue that 'point-hunting' or 'greenwashing' may become an issue where building owners are only concerned about gaining the required points for certification without actually addressing pertinent issues relating to energy efficiency and resource preservation. Saunders (2008) notes that different standards are used in different SRTs and this makes it difficult to do comparisons between tools. Based on a normalised set of conditions, Saunders (2008) claims that LEED (US) uses a less rigorous, and to a certain extent 'lower' building code standard compared to Green Star (Australia) or BREEAM (UK).

An analysis of fourteen mainstream SRTs for buildings/infrastructure is carried out (see Tables G1, H1 and I1 in Appendices G, H and I), and covers: criteria and subcriteria; nature of the scoring used; and identification of international standards embedded. See Chapter 2 for discussion on the standards. The following limitations are summarised from this analysis:

(i) From Table G1, it is observed that there is a very strong environmental focus, with little consideration for other aspects of sustainability such as economic or social factors, except for ASPIRE. Support for this view comes from Fenner and Ryce (2008, p. 56), who maintain that current tools simply 'fail to adequately take into account social and economic indicators'. SRTs such as BREEAM, LEED, Green Star and HK-BEAM among others do not include financial aspects. Ding (2008, p. 456) argues that this may 'contradict the ultimate principle of a development as financial return is fundamental to all projects'. From Table I (Appendix I), it is clear that ISO 14001, concerning environmental management, is the most commonly embedded standard across SRTs over international standards (for example, AS/NZS 4801, EMAS, ISO 9001 and OHSAS 18001).

(ii) The approach to scoring is rigid. See Table H1 for details. All SRTs analysed have adopted deterministic scoring which does not account for variability in value judgements, while seven out of fourteen SRTs do not consider criteria weighting. SRTs largely ignore uncertainty in behavioural issues, which have the potential to affect a building's overall performance. Fenner and Ryce (2008) also argue that assessors' opinions tend to differ and therefore inconsistencies are unavoidable.

(iii) There are issues over benchmarks and relative comparisons, based on the tools' scoring. Sharifi and Murayama (2013) argue that the benchmarks set are non-scientific. Mitchell (2010) claims that Green Star, for example, has been criticised for being too idealistic, showing hallmarks of something developed by architects rather than people with practical experience in the commercial building industry. This is not helped by the lack of published reasoning behind the scores allocated for each criterion, further suggesting that users are merely applying these tools without really understanding what lies behind the tools. Berardi (2012) claims that the reasons behind the selection of criteria and weight are not explicit. Ding (2008) mentions this issue as well. SRTs are designed based on opinions, as opposed to a rigorous analysis of building/infrastructure effects on the environment, economy and society (Fard, 2012; Fowler and Rauch, 2006; Rumsey and McLellan, 2005; Udall and Schendler, 2005). Fenner and Ryce (2008) highlight that building SRTs rely heavily on designers to estimate the amount of energy and resources consumed by building occupiers.

(iv) The tools do not sufficiently account for possible project variations. The regimented scoring is done at a subjective level and does not allow for sufficient differentiation. Sharifi and Murayama (2013, p. 80) explain this limitation, with reference to BREEAM: '… to maintain a minimum point the developer should demonstrate that 50–74% of the development site that was built on previously developed/brownfield land will be brought back to use ... the problem is there is no justification for setting 50% as the minimum and awarding the same points for two different projects that have corresponding percentages that are in the same range but with significant differences.' As another example, in the LEED material reused criterion, 1 point is awarded if 5% of materials are reused out of the total value of the project, and 2 points if 10% of materials are reused. This may not sufficiently account for possible variations. For example, 5% of reused materials for a large project compared to 5% of reused materials in a small project have different environmental impacts.

In contrast to the claimed benefits of engaging with SRTs, as noted above, a few researchers have challenged their usefulness. Newsham et al. (2009) find that 28–35% of LEED certified buildings actually use more energy than traditional buildings. Torcellini et al. (2006) find that actual energy usage in six 'high-performance' buildings is higher than predicted.

This chapter also investigates whether there is any value in obtaining higher Green Star awards (buildings), as compared with the base award of 4 stars. (Green Star only certifies buildings that achieve 4, 5, or 6 stars. Buildings that do not meet at least the minimum 4-star requirement are not publicly-disclosed.) Two databases are compared: one from the Green Star website (GBCA, 2012c) which rates buildings based on adherence to specific sustainable design specifications; and the second from the NABERS website (NABERS, 2012), which rates buildings by measuring energy and water efficiency. Table 3.15 shows the comparison, where data were available.

From Table 3.15, it is seen that a better Green Star award does not necessarily mean better performance in terms of energy and water efficiency (using NABERS award as a gauge of building performance). For example, although the building occupied by E has a higher Green Star award (6 Star) compared to the building occupied by B (5 Star), the NABERS award (Energy) is lower for E (3.5 Star) compared to B (5 Star). It could be that the aforementioned limitations in SRTs (namely that they do not sufficiently account for variations, have subjective benchmarks, among others) result in this conclusion. Naturally, this casts doubt over the reliability and effectiveness of current SRTs. This also raises the concern that building developers might select the SRT that results in the highest rating. Further investigation is warranted to validate the findings presented here.

Buildings	Green Star award (Design)	NABERS award (Energy)	NABERS award (Water)
A	4 Star	5 Star	5.5 Star
B	5 Star	5 Star	3.5 Star
C	6 Star	4.5 Star	n/a
D	4 Star	4.5 Star	n/a
E	6 Star	3.5 Star	n/a
F	4 Star	3.5 Star	4.5 Star
G	6 Star	n/a	2 Star

Table 3.15 Comparison between Green Star and NABERS (as of 20/5/2012). n/a = not available.

3.6 Conclusion

This chapter provides an overview of the various SRTs used for sustainable development of building/infrastructure projects. The chapter gives a compilation of information about the criteria and scoring used in SRTs. Empirical research that has been conducted on the benefits of SRTs and a detailed critique of SRTs are reviewed in this chapter. Some of the limitations identified of current SRTs include: the overemphasis on environmental issues rather than the adoption of a balanced view including both social and economic considerations; rigid scoring which does not account for uncertainty or variability in assessors' perceptions; inadequate definition of scales to permit differentiation among projects; and the existence of non-scientific benchmarks.

CHAPTER 4 – ESG AND ITS INFLUENCE ON FINANCIAL PERFORMANCE OF COMPANIES

4.1 Introduction

In recent years, there is notable growth in the number of institutional investors promoting the concept of socially responsible investing (SRI). SRI is an investment process which recognises that companies are confronted with environmental, social and governance opportunities and risks (now widely referred to as ESG or sustainability practices of companies) that may significantly affect their financial performance. The SRI process involves identifying and investing in companies that meet certain standards or ESG criteria (O'Rourke, 2003). As a result, companies are now pressured to address analysts' concerns not only on financial performance issues but also on ESG matters.

Empirical research focusing on the link between ESG and financial performance is still inconclusive (see Poelloe, 2010; Evans and Peiris, 2010; Gompers et al., 2003; Kreander et al., 2005 inter alia). The aim of this chapter is to address the first research question through a more rigorous research set up and dealing with the limitations of previous studies. This chapter departs from other literature in a few ways. First, existing research in this area largely focuses on individual aspects of sustainability rather than taking a holistic view encompassing environmental, social and governance factors (see, for example, Barnett and Salomon, 2005; Clarkson et al., 2008; Poelloe, 2010; Benito and Benito, 2005).

Second, financial performance tends to be narrowly defined. Much of the existing literature targets largely the analysis of the effects of corporate social responsibility on portfolio performance (Abramson and Chung, 2000; Brammer et al., 2006; Gompers et al., 2003; Schröder, 2004; Statman, 2000; Cortez et al., 2009; Edmans, 2007; Oehri and Faush, 2008; Olsson, 2007), rather than incorporating a wide range of financial ratios necessary to provide a good and accepted benchmarking of a company's financial performance, characteristics and credentials (Barnes, 1987; Yee and Cheah, 2006; Balatbat et al., 2010).

Third, this chapter is motivated by the lack of academic research on the relationship between ESG and company performance, particularly in Australia where mainstream investors are taking steps toward ESG integration in their investment decision processes. This is demonstrated by the growing number of Australian signatories to the United Nations Principle of Responsible Investment (UNPRI) with global assets under management of approximately US$876 billion (RIAA, 2010). Despite the mainstreaming of ESG analysis in Australia, large data providers such as Bloomberg and KLD Research and Analytics (now part of MSCI) only track the ESG performance of large Australian companies that are part of the S&P Index. Other studies have used data primarily from the US and Europe in deriving their conclusions and hardly control for effects from different industry sectors. Wanderley et al. (2008) find that the country of origin has a stronger influence than industry sector, suggesting that ESG could be influenced by political culture, socioeconomic situations and legislation.

Acknowledging the aforementioned limitations in previous studies, this chapter addresses all of these gaps by conducting a rigorous empirical study exploring the link between ESG (with a broader focus) and financial performance (using a range of financial ratios) while controlling for both country and the nature of different industry sectors.

The chapter first provides an overview of current perceptions that exist on socially responsible practices. Then, it proceeds with an outline of the empirical study undertaken, including a discussion on the data sample selection, component industry sectors, and financial ratio selection. The core findings of the research are presented in five parts: I. Cumulative frequency plots of ESG scores as well as quartile comparisons across industry sectors. II. Correlation between financial performance and ESG scores for all companies combined and for each industry sector. III. A multi-linear regression analysis on the relationship of other company factors such as size, leverage and growth on ESG score. IV. Portfolio analysis of ESG leaders and laggards. V. Analysts' forecast analysis. The conclusions then follow.

4.2 Background

Instrumental stakeholder theory (see Donaldson and Preston, 1995) is influential in forming the chapter's first proposition. Based on this theory, the satisfaction of stakeholders (not just shareholders) is assumed to be pivotal to achieving good financial performance. '...studies have tended to generate 'implications' suggesting that adherence to stakeholder principles and practices achieve conventional corporate performance objectives as well or better than rival approaches' (Donaldson and Preston, 1995, p. 71). Hill and Jones (1992) elaborate on how the management of stakeholder relationships might act as a monitoring tool to help managers focus on financial goals (Orlistzky et al., 2003). Freeman and Evan (1990) claim that when managers address multiple stakeholder needs, the efficiency of organisations increases and this is expected to translate into financial gains. Evans and Peiris (2010) explain that a more fundamental reason for financial performance due to ESG related influences is that companies exhibiting strong sustainability practices are likely to have superior management. Similarly, they cite the reliance on instrumental stakeholder theory claiming that successful companies are not only 'responsible to shareholders, but also rely on management of a variety of stakeholders who have a stake in the social and financial performance of the company'. The stakeholder approach shifts a company's focus 'towards a group of critical stakeholders including shareholders, owners, employees, management, customers, suppliers, communities and the environment'(Evans and Peiris, 2010, p. 4). As a result of this, business strategies directed at successful stakeholder management and reflecting overall management strength according to Evans and Peiris (2010) will determine the quality of a company's sustainability practices and are usually positive for financial performance. Heal (2004) maintains that CSR is an important part of corporate strategy as it helps improve staff morale and has an impact on the stock market's assessment of a company's risk. He also elaborated further on the role of CSR and its link to financial performance which encompasses: risk management - where the cost of conflicts with other non-governmental organisations (NGOs) can be very high; waste reduction - where companies are starting to see savings from better management of materials and processes; regulatory protection – where heavily-regulated industries such as oil and gas or mining stand to gain in terms of applications for exploration permits; brand equity - arguing that consumers are sensitive to companies' positions on CSR and would react to them in their purchasing decisions. These arguments also correspond to the discussion by Bénabou and Tirole (2010, pp. 9-11) on the 'visions of CSR' (Vision 1:'Win-Win' and Vision 2: 'Delegated philanthropy') where the upshot is that CSR is all about taking a long-term perspective to maximising profits.

Consequently, a strong positive correlation could be expected between the financial performance of companies and ESG score. This argument leads to the chapter's first proposition:

Proposition P4.1: There is strong positive correlation between the financial performance of companies and ESG score, across industry sectors.

P4.1 is tested through: a one-to-one correlation analysis between various financial ratios and ESG score; a multi-linear regression analysis; and an examination of the returns and variances of the portfolios of ESG leaders (defined as the group of companies that have achieved improvement or consistent ESG scores over the study period) and ESG laggards (defined as the group of companies that have deteriorated ESG scores over the study period).

A study conducted by Deloitte, CSR Europe and EuroNext, which surveyed approximately 400 mainstream fund managers and financial analysts, shows that approximately 80% of the respondents claim social and environmental management to have a positive impact on a company's market value in the long-term, while 50% indicate that they use CSR information provided by management (Deloitte, CSR Europe and EuroNext, 2003). Dhaliwal et al. (2011) also found that the issuance of CSR reports is positively associated with the accuracy of analysts' forecasts. However, currently missing in this area of research is evidence of studies focusing on the impact of ESG performance on the accuracy of analysts' forecasts. This needs to be explored due to its possible implications; if the accuracy of analysts' forecasts increases due to better ESG performance, companies may be more motivated to focus on improving their sustainability practices and reporting, knowing that such information may be used by analysts in gauging the performance of their companies.

In this chapter, it is anticipated that analysts' forecasts accuracy will be better for companies with better ESG performance. This leads to the chapter's second proposition:

Proposition P4.2: ESG performance is negatively associated with analysts' forecasts error.

4.3 Socially responsible practices

Different views exist on socially responsible practices and investing.

(i) Some authors argue that ethical portfolios tend to underperform over the long-term due to lack of diversification (Markowitz, 1952) and that the extra cost, that is involved in screening, negatively impacts the net return (Bauer et al., 2007; Hamilton et al, 1993; Angel and Rivoli, 1997). Angel and Rivoli (1997) argue that the exclusion of companies is considered a form of market segmentation; based on finance theory the effect of this is an eventual rise in the cost of equity capital due to a lack of demand from socially responsible investors, and this in turn decreases the profit associated with the company's activities. Wagner and Schaltegger (2003) argue from a neoclassical environmental economics viewpoint that the aim of environmental regulations is to reduce negative externalities which diminish social welfare. This, however, creates additional costs and affects profit. Empirical studies such as that conducted by Poelloe (2010) found social responsibility to be negatively correlated with financial performance. Evans and Peiris (2010) also found that a company's involvement in more general social issues contributed negatively to both operating performance and stock return. Manescu (2011), based on US data for the period July 1992 to June 2008, suggests that the only positive effect found between one ESG criterion (community relations) on risk-adjusted stock returns could have most likely been attributed to mispricing rather than a compensation for risk, further arguing against the existence of any positive correlation between sustainability practices and market performance. Lopez et al. (2007) examine the multi-dimensional construct consisting of economic, environmental and social indicators of 55 companies on the Dow Jones Sustainability Index (DJSI) and of 55 companies on the Dow Jones Global Index (DJGI), and find a negative relationship between sustainability and corporate performance for the period 1998 to 2004.

(ii) An opposing view is that ethical investing has a positive impact on the bottom line of an organisation and market performance. Support for this view comes from Abramson and Chung (2000), Derwall et al. (2004), Gompers et al. (2003), Opler and Sokobin (1995), Orlitzky et al. (2003) and Lo and Sheu (2007). Abramson and Chung (2000) argue that it is possible to create a consistently diversified subset of value stocks, and that socially responsible investors may not necessarily just pick stocks limited to socially responsible indices but may select other attractive value stocks, outside of these indices, which may qualify as being 'socially responsible' depending on each investor's own parameters. Abramson and Chung (2000) and Hickman et al. (1999) find that risk-adjusted returns might actually be improved by having more stringent stock selection and applying active industry sector weightings. Derwall et al. (2004) conclude that high ranked portfolios (based on eco-efficiency scores) have higher average returns compared to lower ranked counterparts (study period 1995 to 2003). Gompers et al. (2003) find that companies with stronger shareholders' rights have higher value, higher profits, higher growth and lower capital expenditure. The meta-analysis of Orlitzky et al. (2003), across 52 studies using data for the period 1972 to 1997, found that there is a positive association between corporate social practices and financial performance. Bnouni (2010) demonstrates that a positive relationship between CSR and financial performance does not just take place in large organisations, but also across small and medium sized enterprises (SMEs). Ameer and Othman (2012) find a significantly higher mean sales growth, return on assets, profit before taxation and cash flow for companies that have superior sustainability practices compared to those that do not engage in such practices. Eccles et al. (2011) maintain that 'high sustainability' companies outperform their counterparts in terms of accounting measures and stock performance over time. Roberts and Dowling (2002), Clark and Hebb (2005), Kok (2008) and Hebb et al. (2010) claim that companies with good corporate reputations are able to sustain their performance because their intangible characteristics are difficult to replicate. Supporting this view, Adams and Zutshi (2004) argue that sustainability strategies, that have not previously been adopted by companies, can give an added advantage. Some research investment reports (Briand et al., 2011; RIAA, 2010) support this view. Briand et al. (2011) reason that one common motivation for integrating ESG into the investment process is to actively manage key drivers of risk and return. For example, climate change is expected to cause volatility in commodity prices stemming from drastic changes in weather patterns, and hence companies that are able to demonstrate forward-looking strategies are more likely to have a competitive advantage over laggards who may suffer unanticipated costs. Thus, including ESG in investment decisions is considered a form of good risk management.

(iii) A third neutral school perceives that ethical and non-ethical investing yield similar results and that there is no real differentiation between them. Support for this view can be found in Kreander et al. (2005), Scholtens (2005), Hoepner et al. (2011), Gregory and Whitaker (2007), Bauer et al., (2002) and Cummings (2000). Kreander et al. (2005) claim that returns on socially responsible investment (SRI) funds on average have similar performance to regular funds. Scholtens (2005) finds that the performance differential between Dutch socially responsible mutual funds and regular investments between 2001 and 2003 is not significant. Hoepner et al. (2011) did not find any evidence that aggregating or disaggregating corporate environmental scores into pension funds have detrimental financial effect while Gregory and Whitaker (2007) show that neither SRI nor non-SRI UK funds exhibit significant under-performance for risk/style adjusted basis.

A summary of findings up until 2009 is contained in a joint report published by Mercer and the Asset Management Working Group of the United Nations Environment Programme Finance Initiative (Mercer and UNEP FI AMWG, 2007). The report examines a total of 36 studies, selected on the basis that they were either published in peer-reviewed journals, provided a variety of different ESG factors under review, or were considered influential in widening the application of traditional finance theory to non-financial factors. While a majority (55.5%) of these studies exhibit a positive relationship between financial performance and ESG factors, it is interesting to note that only a small proportion (22.2%) have an equal focus in all three areas of ESG.

There appears to be only one existing study which has explored this area of research based on Australian data, which is the data set used in this chapter; however, the measurement used in that study for CSR is restrictive - a value of 1 is used if a company has adopted CSR, and 0 is used if it has not (Brine et al., 2007). Such a measurement is merely on the existence of CSR, and not an exploration of its extent. The data used in this chapter and obtained from the Experts in Responsible Investment Services (EIRIS) provide an assessment of ESG extent, making this chapter's study more complete.

EIRIS is a global provider of research into corporate environmental, social and governance performance. In 2006, EIRIS developed a framework based on three dimensions – social, environmental and ethical (SEE) – to evaluate risks and opportunities confronting industry. EIRIS has also identified relevant 'risks' based on specific industry sectors, and these are referred to as 'industry sector profiles'. These sector profiles are particular to each industry. For example, key issues for the construction industry sector are community approval, resource use, biodiversity, tropical timber, ethics and bribery, whereas general retail has issues of product safety, customer satisfaction, supply chain and environmental impacts. EIRIS scores companies by assigning points or values, which can be either positive or negative. The scoring mechanism uses an ordinal scale, where 3 represents a high positive and -3 represents a high negative for the listed criteria. 87 different criteria are covered spanning across the environmental, social and governance dimensions addressing pertinent issues, which are of primary concern to stakeholders. EIRIS results are used as a basis for this study in establishing ESG scores.

4.4 Data and research methods

This section discusses the company sample selection and its breakdown into industry sectors. It also details the measures used to represent profitability ratios and equity valuation, as well as the statistical methods used in the analysis.

Sample selection

ESG scores for the three-year period 2008 to 2010 for the top 300 companies listed on the Australian Stock Exchange (referred to here as the 'Top 300') are obtained from the EIRIS database through Corporate Analysis Enhanced Responsibility (CAER), a global provider of independent research into ESG performance of companies. (The KLD database is not used because of the limited amount of ESG data for the Top 300). The companies are then categorised into 11 industry sectors: construction; banking and financial services; mining; food and beverage; media; travel and leisure; energy and utilities; industrial; oil and gas producers; general retail; and support services. Other industry sectors such as automobiles and parts, chemicals and forestry have been excluded from this study because the total sample analysed involves only the Top 300, and hence the sample size for these other industry sectors is not large enough for any meaningful conclusions to be drawn.

Not all the companies examined have complete sets of financial ratios. For example, in the banking and financial services sector, some companies have no data on return on invested capital (ROIC). Such companies are omitted from the analysis.

The final sample of 208 companies consists of the following: construction (8%); banking and financial services (11%); oil and gas producers (10%); mining (19%); general retail (7%); industrial (14%); media (6%); food and beverage (5%); energy and utilities (7%); support services (9%); and travel and leisure (4%).

Methodology

To depict the proportion of companies achieving a certain ESG score, cumulative frequency distributions and their associated quartile values are developed from the EIRIS data. This permits benchmarking across industry sectors.

The strength of the correlation between company financial performance and ESG scores is tested. Financial performance indicators include profitability financial ratios and equity valuation (Barnes, 1987). A total of 12 financial performance indicators (see Appendix J for formulae) are used:

(1) Profitability (5 measures):

- Return on assets (ROA)
- Return on equity (ROE)
- Return on invested capital (ROIC)

- Earnings before interest tax depreciation and amortisation (EBITDA) margin
- Net operating profit less adjusted taxes (NOPLAT).

(2) Equity valuation (7 measures):

- Earnings per share (EPS)
- Dividend per share (DPS)
- Dividend yield (DY)
- Price to earnings ratio (PER)
- Enterprise value (EV)
- Market capitalisation to trading revenue (MC/TR) ratio
- Price to book value (P/BV).

Data needed for these measures are obtained through authorised access to the databases of FinAnalysis (n.d.) and the Securities Industry Sector Research Centre of Asia-Pacific (SIRCA).

For the portfolio analysis, ESG leaders are defined as having consistent or improved ESG performance, whereas ESG laggards are defined as those with deteriorated ESG performance over the three-year period 2008 to 2010.

In the analysts' forecast analysis, the forecast horizon is limited to two years because the sample size shrinks drastically for forecasts made three years ahead. A distinction is made between 1-year horizon forecasts and 2-year horizon forecasts because forecast errors tend to get larger as the forecast horizon increases (De Bondt and Thaler, 1990). Forecast error and EPS are both obtained from the I/B/E/S (n.d.) database for the period 2008 to 2010. This is done to ensure consistency in the data. The I/B/E/S database provides global current and historical earnings information and spans 45 countries and over 12,000 companies.

4.5 Results

Part I

Cumulative frequency plots

Figures 4.1 (a) – (c) show a comparison of ESG scores across all industry sectors. The worst performing industry sectors are oil and gas and mining throughout the period 2008 to 2010, where a relatively high proportion of companies in those industry sectors achieved mostly negative ESG scores. The industrial, energy and utilities, and construction industry sectors are ranked ninth, eighth and seventh respectively in terms of ESG scores. These findings are in line with the 'Top 10 industry sectors' identified as having the most pertinent ESG issues (Maier, 2007). This result may have been anticipated because industry sectors such as oil and gas, mining and construction are commonly labelled with the '3D' image (dirty, difficult and dangerous) (ILO, 2001). The banking and financial services industry sector clearly outperforms the other industry sectors. The maximum ESG score recorded for all industry sectors throughout the three-year study period, using the same pool of companies, was 46, while the minimum score was -23.

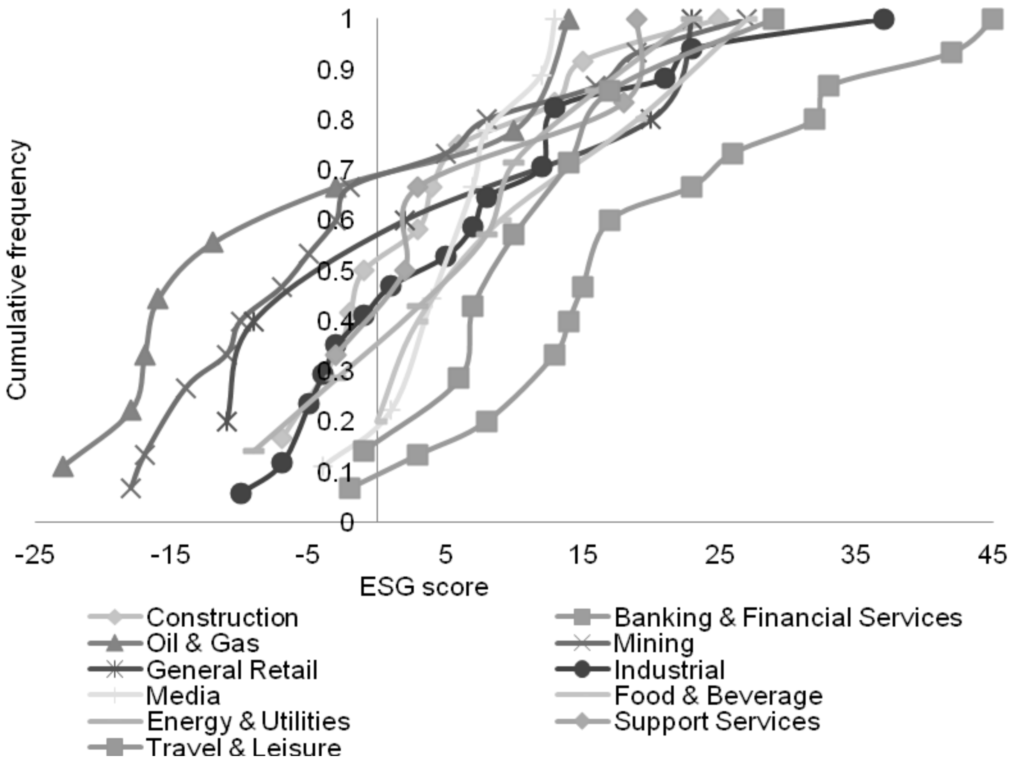


Figure 4.1a. Cumulative frequency plots of ESG 2008 scores by industry sector.

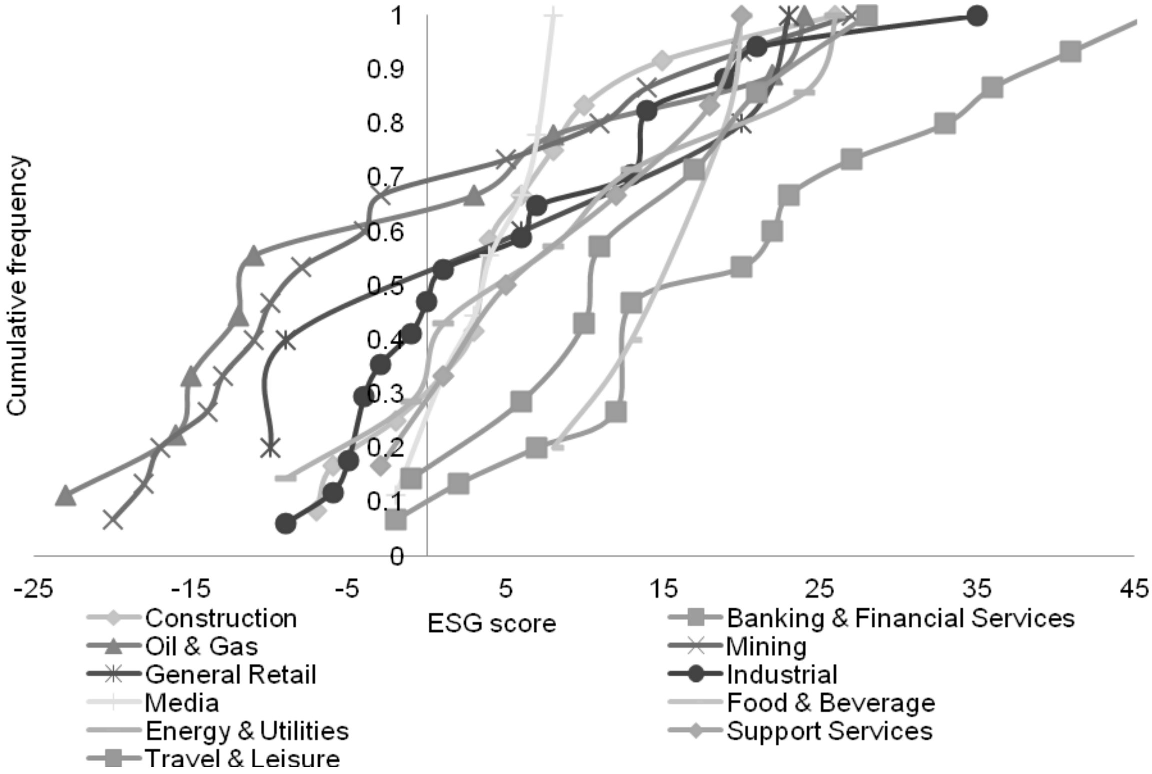


Figure 4.1b. Cumulative frequency plots of ESG 2009 scores by industry sector.

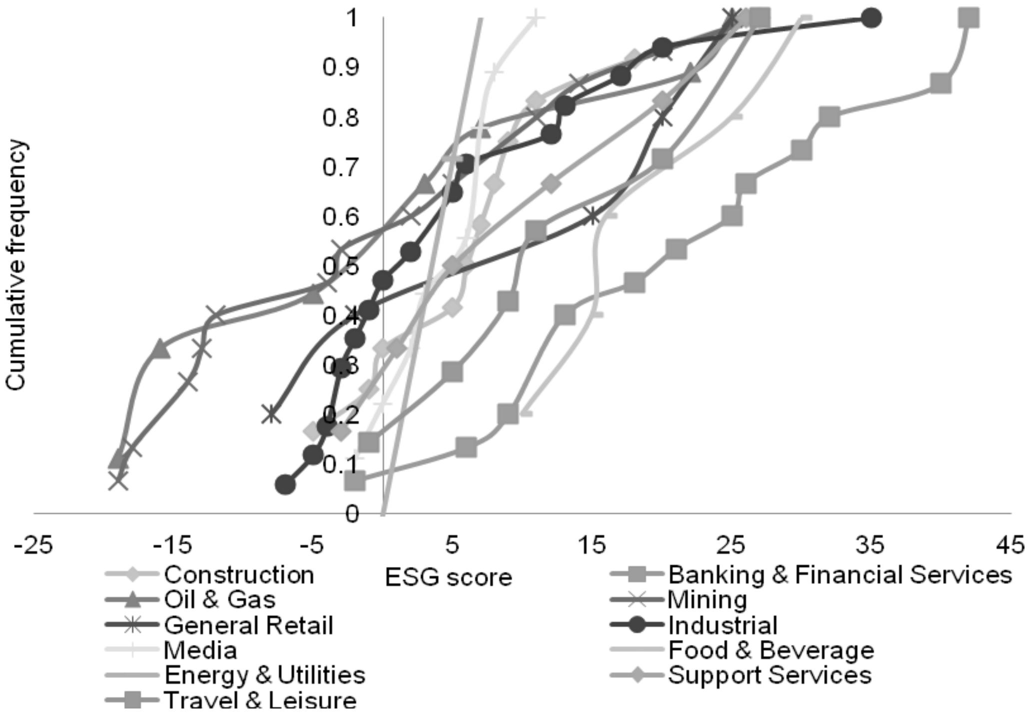


Figure 4.1c. Cumulative frequency plots of ESG 2010 scores by industry sector.

Quartile comparisons across industry sectors

Table 4.1 shows the quartile comparisons (25%, 50%, and 75%) across industry sectors for the period 2008 to 2010. Using the same pool of companies, the banking and financial services sector scores the highest median (50% quartile) at 17, 20 and 21 for 2008, 2009 and 2010 respectively, while the oil and gas sector has the lowest median at -12 and -11 for both 2008 and 2009, but shows improvement in 2010 with a median score of 3. The oil and gas sector also has the lowest quartile score at -18 in 2008.

Industry sector	**Quartiles (2008)**			**Quartiles (2009)**			**Quartiles (2010)**		
	25%	50%	75%	25%	50%	75%	25%	50%	75%
Construction	-3	1	11	-1.3	4	9.5	-0.8	6.5	10.5
Banking and financial services	13	17	32	12	20	33	13	21	32
Oil and gas	-18	-12	12	-15.5	-11	15	-16	3	14.5
Mining	-14	-5	8	-14	-8	11	-14	-3	11
General retail	-10	2	22	-9.5	6	21.5	-5	15	22.5
Industrial	-5	5	13	-4	1	14	-3	2	12.5
Media	3	7	10	1	4	7.5	1	6	7.5
Food and beverage	2	9	23	10.5	19	19.5	12.5	16	27.5
Energy and utilities	-3	8	16	-1	8	24	-1	14	23
Support services	-3	3	18	0	8.5	19.5	0	8.5	21.5
Travel and leisure	6	10	17	6	11	21	5	11	27

Table 4.1. Quartile ESG scores by industry sector.

Part II

Correlation coefficients

Chand (2006) suggests that distinguishing by industry type allows for clearer analysis to be made between CSR and financial performance. However, using data for the period 2008 to 2010 broken into industry sectors, the correlation coefficients relating financial performance and ESG scores, as shown in Table 4.2, indicate no strong correlation.

In Table 4.2, negative values are given inside parentheses; negative values indicate that as the ESG score decreases, financial performance increases, and vice versa. (The p-value is an indicator of the decreasing reliability of the result. That is, the higher the p-value, the less can it be believed that the observed relation from the sample between the variables is a reliable indicator of the relation between the respective variables in the population – see, for example, Hill and Lewicki (2006). Typically, a p-value of either 0.05 or 0.1 is treated as an acceptable level of error. For a p-value found to be less than 0.05 or 0.1, the result observed is said to be statistically significant.)

Industry sector	**ROE**	**ROA**	**ROIC**	**EBITDA**	**NOPLAT**
Construction	(0.05)	(0.11)	0.08	(0.21)**	(0.23)*
Banking and financial services	(0.18)**	(0.13)	0.19**	0.01	0.07
Oil and gas producers	0.09	0.016	0.04	(0.005)	0.39
Mining	0.14**	0.12	0.12	0.16**	0.16**
General retail	(0.12)	(0.31)*	0.04	0.07	0.09
Industrial	(0.18)	0.05	(0.05)	(0.12)	(0.10)
Media	0.09	0.35*	(0.32)**	(0.19)	(0.19)
Food and beverage	0.71*	0.67*	0.41**	0.49**	0.45*
Energy and utilities	0.16	0.15	0.27	0.06	0.07
Support services	(0.37)**	(0.45)	(0.35)	(0.52)**	(0.48)*
Travel and leisure	(0.12)	(0.17)	0.13	(0.16)	(0.18)

Table 4.2a Correlation coefficients by industry sector; profitability ratios. (* p-value < 0.1
** p-value < 0.05)

Industry sector	EPS	DPS	DY	PER	EV	MC/TR	P/BV
Construction	0.54*	0.29*	(0.27)*	0.02	0.27**	0.18	0.00
Banking and financial services	0.24**	0.23**	(0.07)	0.27*	0.77*	0.06	0.19
Oil and gas producers	0.58*	0.62*	0.18	0.02	0.64*	(0.01)	(0.10)
Mining	0.16*	0.48*	(0.30)**	0.08	0.52*	(0.16)**	0.04
General retail	0.34**	0.46*	0.02	0.18	0.58*	0.03	(0.05)
Industrial	0.24*	0.32	(0.05)	(0.18)	(0.01)	(0.30)*	0.14
Media	0.37*	(0.17)	0.44*	0.31**	(0.55)*	(0.36)*	0.07
Food and beverage	0.17	0.46**	0.50**	0.23	0.54*	0.25	0.67*
Energy and utilities	0.57*	(0.13)	0.00	(0.10)	0.61*	(0.67)*	0.05
Support services	0.19	0.39*	(0.11)	0.35	0.43*	(0.33)	(0.17)
Travel and leisure	(0.05)	0.09	0.37	0.04	0.83*	(0.31)	(0.26)

Table 4.2b Correlation coefficients by industry sector; equity valuation. (* p-value < 0.1
** p-value < 0.05)

Commentary by industry sector follows. Two related symbols are used here:

r correlation coefficient; r provides an indication of the direction and magnitude of correlation.

r^2 coefficient of determination; r^2 provides an indication as to how much variation in one variable can be accounted for by variation in the other variable.

Construction

From Table 4.2a, it can be observed that there is weak negative correlation ($r < 0.5$) with the profitability ratios except for ROIC where $r = 0.08$. The coefficient of determination (r^2) is less than 0.5 for all the measures; that is, less than 50% of the variation in a company's bottom line can be explained by variation in its ESG score. Hence, there is not enough evidence to justify the claim that there is strong positive correlation between profitability and ESG scores within the construction sector. Under equity valuation, the analysis shows that EPS has a strong correlation with ESG score where $r = 0.54$ and is statistically significant at p-value < 0.1, while all the remaining six measures exhibit a weak correlation with ESG scores, although four (DPS, $r = 0.29$;PER, $r = 0.02$; EV, $r = 0.27$; MC/TR, $r = 0.18$) of these suggest an increasing trend line. Proposition P4.1 (for the construction sector) is therefore rejected.

Banking and financial services

EV exhibits a reasonable positive correlation ($r > 0.5$) with ESG score and is statistically significant (p-value < 0.1). The remaining ratios from Tables 4.2a and 4.2b have weak correlation with ESG score, though generally positive, except for ROE, ROA and DY. Both EPS and DPS are positively correlated to ESG score and are statistically significant at a p-value < 0.05. Proposition P4.1 (for the banking and financial services sector) is therefore rejected.

Oil and gas

A positive trend ($r > 0$) is observed, with all profitability ratios used except for EBITDA, though the correlation coefficients are too small to support any strong relationship. Analysing the coefficients for the equity valuation measures and ESG score, a reasonable positive correlation is observed for EPS ($r = 0.58$, p-value < 0.1), DPS ($r = 0.62$, p-value < 0.1) and EV($r = 0.64$, p-value < 0.1). This gives r^2 values of 0.34, 0.38 and 0.41 indicating that approximately 34% of the variation in data for EPS, 38% of the variation in data for DPS and 41% of the variation in data for EV can be accounted for by variation in the ESG score.

Although strong and sustained EPS values might be anticipated because the oil and gas sector could be expected to have large market capitalisation and possibly strong market dominance, the EPS performance for this particular dataset is found to be poor compared to other industry sectors. The ESG scores for this sector are also found to be poor, with companies having both low EPS values and low ESG scores influencing the correlation.

Because a large majority of the measures show weak correlation ($r < 0.5$) with ESG score, proposition P4.1 (for the oil and gas sector) is rejected.

Mining

The relationships between all profitability ratios and ESG score show positive linear trends. No strong correlation is found across all the financial ratios used ($r < 0.5$) except for EV. Both EPS and DPS are positively correlated to ESG score and are found to be statistically significant, with $r = 0.16$ (p-value < 0.1) and $r = 0.48$ (p-value < 0.1) respectively. Nevertheless, considering the generally weak correlations across all measures, proposition P4.1 (for the mining sector) is rejected.

General retail

ROE and ROA are found to have a negative correlation with ESG score, where the correlation coefficients involving both ROE and ROA are -0.12 and -0.31 respectively. The correlation is not strong when equity valuation measures are used (EPS, $r = 0.34$; DPS, $r = 0.46$, DY; $r = 0.02$, PER; $r = 0.18$; MC/TR, $r = 0.03$; P/BV, $r = -0.05$) with the exception of EV where $r = 0.58$ and this is statistically significant (p-value < 0.1). Proposition P4.1 (for the general retail sector) is rejected.

Industrial

For all twelve measures, there is no strong correlation with ESG score. Of the measures, eight show a negative relationship with ESG score (ROE, $r = -0.18$; ROIC, $r = -0.05$; EBITDA, $r = -0.12$; NOPLAT, $r = -0.10$; DY, $r = -0.05$; PER, $r = -0.18$; EV, $r = -0.01$ MC/TR, $r = -0.30$) while the others show a positive relationship with ESG score but have correlation coefficients less than 0.5. Therefore proposition P4.1 (for the industrial sector) is rejected.

Media

Based on Tables 4.2a and 4.2b, it is clear that none of the correlation coefficients are strong enough to justify a positive link with ESG score. Six out of the twelve measures exhibit a negative relationship (ROIC, $r = -0.32$; EBITDA, $r = -0.19$; NOPLAT, $r = -0.19$; DPS, $r = -0.17$; EV, $r = -0.55$; MC/TR, $r = -0.36$). Consequently, proposition P4.1 (for the media sector) is rejected.

Energy and utilities

No strong correlation is found between profitability ratios and ESG scores. For equity valuation measures, it is found that only EPS and EV depict a reasonable correlation ($r = 0.57$ and $r = 0.61$ respectively) and are statistically significant at a p-value < 0.1. Hence, proposition P4.1 (for the energy and utilities sector) is rejected.

Food and beverage

A reasonable positive correlation exists between all the profitability ratios (ROE, $r = 0.71$; ROA, $r = 0.\ 67$; ROIC; $r = 0.41$; EBITDA, $r = 0.49$; NOPLAT, $r = 0.45$) and ESG score. However, looking at r^2, in only two of the ratios, ROE (0.50) and ROA (0.45), variability can be largely accounted for by variation in ESG score. All the trend lines between equity valuation measures and ESG score depict a positive gradient, but a large majority only show a reasonable positive relationship, except for DY ($r = 0.50$), P/BV ($r = 0.67$) and EV ($r = 0.54$). Consequently, because 60% of the indicators depict a reasonable correlation with ESG, proposition P4.1 (for the food and beverage sector) could possibly be accepted.

Support services

When profitability ratios are examined, all show a negative correlation with ESG score (ROE, $r = -0.37$; ROA, $r = -0.45$; ROIC, $r = -0.35$; EBITDA, $r = -0.52$; NOPLAT, $r = -0.48$). The results for both EBITDA and NOPLAT are statistically significant at a p-value < 0.1. Proposition P4.1 (for the support services sector) is therefore rejected.

Travel and leisure

Generally a negative trend line is observed between profitability ratios and ESG score, with the exception being ROIC. No strong link can be established because of the weak correlation coefficients. The conclusion is similar for equity valuation measures, with the exception of EV ($r = 0.83$, $r^2 = 0.68$) suggesting that 68% of the variation in EV values can be accounted for by variation in ESG scores. Because EV is the only ratio that demonstrates a reasonable relationship with ESG, proposition P4.1 (for the travel and leisure sector) is rejected.

Part III

Multi-linear regression

Because no strong correlation can be established between financial performance measures and ESG score, other predictors (namely size, growth and leverage) that may have an impact on company's performance are examined (Guidara and Othman, 2012, Jia et al., 2010). The following model is examined for the total 2008–2010 data,

$$\text{FinPerf} = \beta_0 + \beta_1\text{ESG} + \beta_2\text{Size} + \beta_3\text{Growth} + \beta_4\text{Leverage} + \beta_5\text{Industry} + \varepsilon \qquad (4.1)$$

where,

β_i, i = 0, 1, …	Constants.
FinPerf	Financial performance as measured by financial ratios.
Size	The logarithm of total assets. A positive relationship might be anticipated between company size and financial performance.
Growth	EPS 1 year growth. Strong earnings growth leads to better financial performance. Hence a positive relationship might be anticipated.
Leverage	Net gearing. A negative relationship might be anticipated between leverage and financial performance; higher gearing ratios indicate that the company is in a less favourable financial position because most activities are funded through borrowings (Padget, 1991).
Industry	A dummy variable related to each industry sector.

Both un-standardised and standardised coefficients are derived in this analysis. The un-standardised coefficients are generated directly from the original data. However, to cater for the variables having different orders of magnitude, whereby one term may dominate over others, standardised coefficients are also derived. The standardised regression coefficients are measured to a similar scale, where the mean is zero and the standard deviation is one. This makes the coefficients directly comparable, and hence a larger coefficient denotes a larger influence on the dependent variable. One difference between standardised and un-standardised regression is that the standardised regression does not have a constant term. Adjusted r^2 values take into account the number of right hand side variables. A hypothesis test is specified with respect to a test statistic, t, given as a function of a sample. The test statistic can be used to determine a p-value which is an indication of how likely the data from the sample is obtained by chance (see, for example, Montgomery and Runger, 2011). The standard error is a measure of variation among the estimates (the un-standardised beta coefficients of the variables) derived from all samples.

The results of the multi-linear regression are shown in Table 4.3 for EV, which is the only measure of financial performance showing statistical significance against ESG score at either $p < 0.05$ or $p < 0.1$. The r value of the EV case is 0.59 ($p < 0.05$), while the adjusted r^2 value is 0.34.

All beta coefficients for ESG are positive except for ROA, EBITDA, NOPLAT, DY, and PER.

Variable	**Un-standardised coefficients**		**Standardised coefficients**	**t-stat**	**p-value**
	β_i	Std. error	β_i		
(Constant)	-1.29E11	1.466E10		-8.795	0.000
ESG	3.655E8	1.042E8	0.169	3.507	0.001
Size	1.637E10	1.630E9	0.501	10.042	0.000
Leverage	-2.429E9	1.213E9	-0.094	-2.003	0.046
Growth	6.371E7	1.422E8	0.018	0.448	0.654

Table 4.3 EV used as a measure of financial performance.

1-year lag analysis

Any new company initiative or implementation could be expected to take time to manifest itself. On this basis, it is anticipated that a lag effect might more accurately capture the impact of ESG on company performance. The following model is examined,

$$FinPerf_{2009} = \beta_0 + \beta_1 ESG_{2008} + \beta_2 Size_{2009} + \beta_3 Growth_{2009} + \beta_4 Leverage_{2009} + \beta_5 Industry + \varepsilon \quad (4.2)$$

The meaning of the variables remains the same as in Equation (4.1), but the year of the data is appended. Only ROIC has ESG as a statistically significant variable. See Table 4.4. The ROIC case has an adjusted r^2 of 0.083.

All beta coefficients for ESG are positive except for NOPLAT, EBITDA, MR and DY.

Variable	Un-standardised coefficients		Standardised coefficients	t-stat	p-value
	β_i	Std. error	β_i		
(Constant)	-1.109	6.490		-0.171	0.865
ESG	0.236	0.058	0.373	4.054	0.000
Size	0.143	0.715	0.019	0.200	0.842
Leverage	-0.306	0.483	-0.065	-0.634	0.527
Growth	-0.006	-0.003	-0.003	-0.032	0.975

Table 4.4 ROIC used as a measure of financial performance; 1-year lag analysis.

2-year lag analysis

This analysis can be extended to a 2-year lag,

$$FinPerf_{2010} = \beta_0 + \beta_1 ESG_{2008} + \beta_2 Size_{2010} + \beta_3 Growth_{2010} + \beta_4 Leverage_{2010} + \beta_5 Industry + \varepsilon \qquad (4.3)$$

The meaning of the variables remains the same as in Equation (4.1), but the year of the data is appended. EV is the only model found to be statistically significant when used as a measure of financial performance ($r = 0.96$; adjusted $r^2 = 0.90$). See Table 4.5. The results in Table 4.5 show that the most significant right hand side variables are Size and Growth. The beta coefficients for ESG are found to be negative for five of the financial ratios, namely ROE, ROA, DY, MR and PBV.

Variable	Un-standardised coefficients		Standardised coefficients	t-stat	p-value
	β_i	Std. error	β_i		
(Constant)	-5.969E10	8.317E9		-7.178	0.000
ESG	4.708E5	6.702E7	0.000	0.007	0.994
Size	6.685E9	9.138E8	0.232	7.512	0.000
Leverage	-2.871E8	9.129E8	-0.010	-0.315	0.754
Growth	1.938E9	6.081E7	0.931	31.864	0.000

Table 4.5 EV used as a measure of financial performance; 2-year lag analysis.

Part IV

Portfolio analysis

The companies are divided into two portfolios, namely ESG leaders and ESG laggards. ESG leaders are defined as a portfolio of companies with either consistent or improved

ESG scores from 2008 to 2010; ESG laggards are defined as a portfolio of companies with deteriorated ESG scores across the same period.

The portfolio return is defined in three ways:

Stock return. Daily stock return given by:

$$\lambda = \log_e\left(\frac{\text{price}_t}{\text{price}_{t-1}}\right) \tag{4.4}$$

where t is the daily closing price of a stock. The annual stock return is obtained by adding the daily stock returns for all trading days in a particular year.

Buy-and-hold return (BHR) given by:

$$\text{BHR}(t_1, t_x) = (\log P_x - \log P_1) \tag{4.5}$$

where the subscript x represents the last trading day of the month, 1 the first trading day of the month, and P the stock price.

To obtain the annual return, the monthly buy-and-hold returns are summed.

Arithmetic return. Daily arithmetic return is given by:

$$\alpha = 100 \times \frac{\text{price}_n - \text{price}_{n-1}}{\text{price}_{n-1}} \tag{4.6}$$

where n = 2, 3, ..., n_x represents the n^{th} data value in days, and n_x is the last trading day of the year.

The average daily return for a company is annualised through,

$$\text{Annualised return} = (1+\alpha)^{365} - 1 \tag{4.7}$$

Companies in each portfolio (ESG leaders and ESG laggards) are weighted equally. The return of a portfolio is determined from,

$$\text{Return} = \sum_i w_i R_i \tag{4.8}$$

where i represents the number of companies in a portfolio, w represents the weight of a stock, and R represents the expected return on stock.

The portfolio returns are shown in Table 4.6. Only BHR shows that the ESG leader portfolio performs better than the ESG laggard portfolio.

Return type	ESG leaders	ESG laggards
Stock return	-0.063	-0.008
Buy-and-hold return (BHR)	-0.067	-0.085
Arithmetic return (AR)	0.010	0.107

Table 4.6 Returns on portfolios.

The variance of both portfolios is also calculated. Portfolio variance is given as a function of the correlations ρ_{ij} of the individual stock, for all of the stock pairs (i,j) as shown in Equation (4.9), and may be taken as an indication of the return variability or return risk of a portfolio.

$$\text{Variance} = \begin{bmatrix} w_1\sigma_1 & \ldots & w_n\sigma_n \end{bmatrix} \begin{bmatrix} 1 & \rho_{12} & \cdots & \rho_{1n} \\ \rho_{21} & 1 & \cdots & \rho_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \rho_{n1} & \cdots & \cdots & 1 \end{bmatrix} \begin{bmatrix} w_1\sigma_1 \\ \vdots \\ w_n\sigma_n \end{bmatrix} \tag{4.9}$$

The portfolio variances are shown in Table 4.7. The highest portfolio variance comes from the ESG laggard portfolio when the arithmetic return is used.

Variance for:	ESG leaders	ESG laggards
Stock return	0.054	0.044
Buy-and-hold return (BHR)	0.068	0.111
Arithmetic return (AR)	0.309	0.615

Table 4.7 Portfolio variances.

Considering that mixed results are obtained in the portfolio analysis, proposition P4.1 is rejected.

Part V

Analysts' forecast analysis

The correlation results for forecast error are shown in Tables 4.8a and 4.8b for, respectively, the 1- and 2-year forecast horizons. Forecast error, denoted FERROR, is defined as the average of the absolute errors of all forecasts made in the year for target earnings, scaled by the stock price at the beginning of the year and is given by,

$$\mathrm{FERROR} = \frac{1}{\mathrm{N}} \sum \frac{1}{\mathrm{Price}_{i,t}} \left| \mathrm{FC}_{i,t,j} - \mathrm{EPS}_{i,t} \right| \tag{4.10}$$

where subscripts i, t, and j denote company, year and forecast, respectively; FC denotes analysts' forecast; and Price denotes stock price at the beginning of the year. The absolute error is found by reducing FC within a specified horizon (j) of a particular company (i) in a given year (t) by the actual EPS value for a particular company (i) in the same year (t). The absolute error for company (i) is then divided by its respective stock price at the beginning of the year. Absolute errors for the company (i) are summed and divided by the total number of forecasts made to obtain FERROR. Both FERROR and EPS are obtained from the I/B/E/S (n.d.) database for the period 2008 to 2010 to ensure consistency in data. Generally, a negative association is seen between FERROR and ESG scores, however, only the food and beverage ($p < 0.05$) sector as well as the travel and leisure ($p < 0.1$) industry sector show statistically significant results, and this is only for the 1-year forecasts. For the 2-year forecasts, only the food and beverage sector shows a statistically significant result ($p < 0.05$).

Industry sector	Correlation coefficient (r)	p-value
Construction	-0.145	0.359
Banking and financial services	-0.064	0.724
Oil and gas producer	-0.195	0.276
Mining	-0.094	0.412
General retail	0.034	0.894
Industrial	-0.248	0.128
Media	-0.416	0.139
Food and beverage	-0.592	0.016
Energy and utilities	0.027	0.913
Support services	-0.060	0.827
Travel and leisure	-0.416	0.086

Table 4.8a Correlation coefficients between FERROR and ESG scores for 1-year forecasts.

Industry sector	Correlation coefficient (r)	p-value
Construction	-0.090	0.584
Banking and financial services	-0.068	0.712
Oil and gas producer	-0.186	0.292
Mining	0.132	0.257
General retail	-0.173	0.506
Industrial	0.157	0.369
Media	-0.071	0.819
Food and beverage	-0.577	0.019
Energy and utilities	-0.346	0.147
Support services	0.290	0.294
Travel and leisure	-0.283	0.287

Table 4.8b Correlation coefficients between FERROR and ESG scores for 2-year forecasts.

A multi-linear regression analysis by industry sector for the period 2008 to 2010 is also done here for the following formula,

$$\text{FERROR} = \beta_0 + \beta_1\text{ESG} + \beta_2\text{Size} + \beta_3\text{Growth} + \beta_4\text{Leverage} + \varepsilon \qquad (4.11)$$

The meanings of β, Size, Growth and Leverage remain the same as used in Equation (4.1). For the 1-year forecasts, only data from the travel and leisure industry sector has ESG as a statistically significant predictor ($p < 0.1$) as shown in Table 4.9. The adjusted r^2 is 0.485.

Variable	Un-standardised coefficients		Standardised coefficients	t-stat	p-value
	β_i	Std. error	β_i		
(Constant)	-0.074	0.045		-1.645	0.126
ESG	-0.001	0.000	-0.563	-1.947	0.075
Size	0.010	0.005	0.546	1.916	0.079
Leverage	0.004	0.003	-0.367	-1.432	0.178
Growth	-0.025	0.008	-0.807	-3.335	0.006

Table 4.9 FERROR as dependent variable, 1-year forecasts.

4.6 Conclusion

An analysis of ESG performance across various industry sectors within the Top 300 reveals that the oil and gas sector and the mining sector achieve the worst ESG scores, while the banking and financial services sector achieves the best ESG score.

A strong positive link between company financial performance and sustainability practices, as measured by ESG scores, could not be established looking at financial performance measures one at a time; a large majority of the regression coefficients fall below the 0.5 threshold, suggesting weak correlation. From the multi-linear regression analysis, although a majority of the correlation coefficients are positive, only one measure of financial performance (EV case) shows ESG as being statistically significant. Both the 1-year and 2-year lag analysis could not convincingly demonstrate a strong correlation between financial performance and ESG. Many negative correlations were observed between financial performance measures and ESG score. From the portfolio analysis, both the stock return and the arithmetic return for the portfolio of ESG leaders are lower by comparison to the ESG laggards. In the analysts' forecast analysis, it was found that generally a negative association exists between the forecast error and ESG scores, however only the food and beverage sector and the travel and leisure sector showed statistically significant results, and this only for 1-year forecasts.

Consequently, proposition P4.1 advanced in this chapter, namely that there is a link between financial performance and ESG scores, is rejected. However, proposition P4.2, namely that ESG performance is negatively associated with analysts' forecast errors, is mildly accepted, because only the food and beverage sector showed statistically significant results for both 1- and 2-year forecast horizons, while only the travel and leisure industry sector had ESG as a statistically significant predictor in the multi-linear regression analysis.

There are a number of possible flow-on conclusions:

- There could possibly be a blurring between certain ESG practices. That is, while some practices may be positively impacting a company's bottom line, other practices may not necessarily be value-adding, but rather only burdening the company with additional cost.
- The impact of ESG on financial performance may not be able to be captured within a time frame of 1 and 2 years, but may require a longer period.
- The ESG scores may not reflect the true ESG practices of companies. Although the EIRIS work covers 87 areas and is arguably one of the most comprehensive measurements available, the scoring mechanism in itself may be subjective.
- The ESG reporting of companies may not allow the reader to fully comprehend those practices in order to score them objectively. It could be that some companies may deliberately choose not to engage in full ESG reporting/disclosures to conceal their 'bad' performance.
- The ESG scores may not have been done by people familiar with and within each industry sector, but rather by people from one or a couple of sectors, thereby introducing scoring bias. For example, if the scoring was done by office-based, non-technical people, they may show a bias in their scoring against the 'dirty' industry sectors, in favour of office-based or non-technical sectors.

CHAPTER 5 – PREDICTING THE BEHAVIOUR OF ESG STOCK PRICES, INDEX TREND AND TRADING VOLUME USING MARKOV CHAINS

5.1 Introduction

This chapter extends the analysis presented in Chapter 4 by focusing on the behaviour of sustainability indices and their constituents (company stocks that make up the composition of the index). Sustainability indices such as the FTSE4Good Australia Index are usually created based on screening a list of companies in accordance to a set of ESG criteria (Jemel-Fornetty et al., 2011). Given the growth of sustainability indices and attention on company stocks that are highly valued in ESG over the last decade (see Chapter 2), there is an urgent need to obtain insights into their underlying properties and whether they have the potential of generating value in the capital markets.

A majority of socially responsible investors claim that ESG performance is a proxy of management quality (Responsible Investor, 2009; MISTRA, 2007; Kruse and Lundbergh, 2010). Companies with high ESG performance are generally believed to be more transparent about their practices and are more likely to have better financial performance (ESG Shares, 2012). As such, it is anticipated that sustainability indices and these company stocks will perform better in the capital markets. As well, a high interest in these stocks could be expected considering the massive growth in the SRI market (Dorfleitner and Utz, 2012). Interest in stocks is usually represented by trading volume. Being able to predict trading volume is important as it is believed to be positively related to the magnitude of price movements (Karpoff, 1987).

The Markov chain theory is seen as a useful tool in testing out the propositions in this chapter (see section 5.2.4) because it aids in making probabilistic statements about future stock price levels, indices and trading volume which is more superior to traditional regression forecasting techniques (Idolor, 2010; Raftery et al., 1993). As well, it allows for the tests of order, stationarity and homogeneity which are important Markovian attributes. The terms homogeneity, stationarity and order are used in the same sense as Fielitz and Bhargava (1973). The test for homogeneity is used in this chapter to investigate if price movement of company stocks belonging to the FTSE4Good Australia Index are similar or unique to each company stock. The test for stationarity is used to investigate if transition probabilities (stock prices, index trend and trading volume) are independent of time. In other words, it checks if the probability associated with movement from one state at a given period to another at a future period is unchangeable. The test for order is used to investigate if observations (stock prices, index trend and trading volume) at successive points in time are independent against the alternative hypothesis that the observations are of the first or higher order Markov chains. The other terms associated with Markov chain theory are described in section 5.2.3.

From the results presented in this chapter, stakeholders can draw conclusions about the behaviour and value of investing in sustainability indices and their constituents. The application of Markov chain theory to the SRI literature is original.

The chapter proceeds with a Background section on the literature concerning financial market prediction, justification as to why the FTSE4Good Australia Index is selected and some necessary concepts on Markov chain theory. The core findings of the research are then presented in three sections: section 5.3.1 – Stock price behaviour; section 5.3.2 – Stock index behaviour; section 5.3.3 – Trading volume behaviour followed by relevant discussions and conclusions.

5.2 Background

5.2.1 Financial market prediction

In general, the prediction of financial markets is known to be a difficult and complex problem due to many factors which interact together disproportionately. Such factors include but are not limited to economic conditions, investors' expectations, political implications, exchange rates and relative performance to other stock markets (Vasanthi et al., 2011; Idolor, 2010). This difficult challenge has led to a number of academic researchers concluding that company stock prices are dynamic and unpredictable

(Turner et al., 1989; Fielitz and Bhargava, 1973; Obodos, 2005; Fama, 1965). On the contrary, for speculators and arbitrageurs who are non-believers of the random walk hypothesis (see Godfrey et al., 1964), stock market prediction is an activity which purportedly allows them to gain future price information (see Wang, 2002; Pai and Lin, 1995; Lee at al., 2004; Afolabi and Olude, 2007; Kim et al., 2006) hence allowing the hedging of market risk and simultaneously offers a good investment opportunity.

To this end, the prediction of financial time series have largely focussed on developed markets such as the UK (Jung and Boyd, 1996) and US (Campbell and Shiller, 1988; Zhu et al., 2008) using a variety of tools. Lam (2004) has used neural network techniques to integrate both fundamental and technical analysis for financial performance prediction using a ten year data series from Compustat. Chang et al. (2011) develop a dynamic threshold decision system to detect stock trading signals while Brownstone (1996) measures the percentage accuracy of neural network predictions in stock market movements across the FTSE 100 Index.

More recent studies have also made attempts to model and forecast stock prices focusing on the emerging markets due to their perceived untapped potential (see Alagidede and Panagiotidis, 2009; Vasanthi et al., 2011; Idolor, 2010; Cheong, 2004). There is also a shift in focus towards stock index prediction because they have a larger influence on investment decision making (Vasanthi et al., 2011). For example, Opong et al. (1999) examine the behaviour of the London Financial Times Stock Exchange (FTSE) All Share 100, 250, 300 equity indices and find that the FTSE stock index return series is not truly random as some cycles appeared more frequently than expected. Dai et al. (2012) propose a stock index prediction model combining non-linear independent component analysis and neural networks. They argue that their model is a suitable alternative for Asian stock market indices. Kara et al. (2011) suggest the use of artificial neural networks (ANN) and support vector machines (SVM) to predict the stock price index movement. ANN is found to be 4.22% better than SVM when experimented with the Istanbul Stock Exchange.

5.2.2 FTSE4Good Australia Index

In deciding which ESG index to analyse, the FTSE4Good Australia Index was selected for a few reasons. Firstly, it uses data from the Experts in Responsible Investment Services (EIRIS) which is seen to be a global leader in the provision of corporate ESG scores. Companies using EIRIS data include large multibillion dollar pension funds such as the French FRR and Danish ATP. Large asset managers such as BlackRock, Legg Mason, Legal and Morgan Stanley use EIRIS data as well (Hoepner et al., 2011); hence, if there is indeed any value relevance in investing in companies with best ESG practices, it is anticipated that this can be seen through the company stocks which are part of the FSTE4Good Australia Index. Secondly, EIRIS has the advantage over other providers of ESG assessments (such as MSCI) because it operates as an independent, non-profit organisation which does not provide financial or legal advice to clients. In other words, there is reason to believe that ESG assessments are objective and have somewhat limited conflict of interest.

5.2.3 Markov chains

Markov chain theory is a useful stochastic process for dealing with complex systems (Taylor, 1996). The two fundamental concepts in Markov chains are states and transitions. The state of a system refers to a set of one or more key variables representing the present situation. At a different time period (n+1), the system may change the state which is currently occupied at time n or remain in the similar state according to a certain probabilistic distribution. Changes from one state to another are known as transition states.

Assume $\Re$ is a finite or countable set of states, that is, values that the random variables X_i may take on. A process X_0, X_1 ...satisfies the Markov property if

$$P\{X_{n+1} = i_{n+1} \mid X_n = i_n, X_{n-1} = i_{n-1}, ..., X_0 = i_0\} = P\{X_{n+1} = i_{n+1} \mid X_n = i_n\}$$

for all n and all $i_0, ..., i_n \in \Re$.

This means that at any given moment, a system has Markov property if the probability that a system occupies a future state X_{n+1} depends only on the current state X_n and not on the other past states $X_0, \ldots X_{n-1}$ (Hillier and Lieberman, 2005).

Markov chain theory defines probabilities that are associated with transition states (see Taylor and Karlin, 1994; Howard, 1971) where p_{ij} represents the probability of moving from state i to state j (also known as transition probabilities). It follows that:

$$\sum_{j=1}^{N} p_{ij} = 1 \tag{5.1}$$

where

$$0 \le p_{ij} \le 1 \tag{5.2}$$

Based on Markov theory, the probability of the process in each state is not dependent on the initial states of the process. The steady state probabilities of the Markov chains are given as π_i (also known as stationary probabilities). Define π_i as the probability of being in state i; i = 1,2,...N and as components of a vector $\boldsymbol{\pi}$. $\mathbf{P}$ is a stochastic transition matrix with components $p_{ij.}$ Then, after Howard (1971):

$$\boldsymbol{\pi} = \boldsymbol{\pi}\mathbf{P} \tag{5.3}$$

with

$$\sum_{i=1}^{N} \pi_i = 1 \tag{5.4}$$

An example of a transition diagram (Figure 5.1) is used to depict the states each labelled with i, j, k, l respectively and the transitions (arrows) between the states.

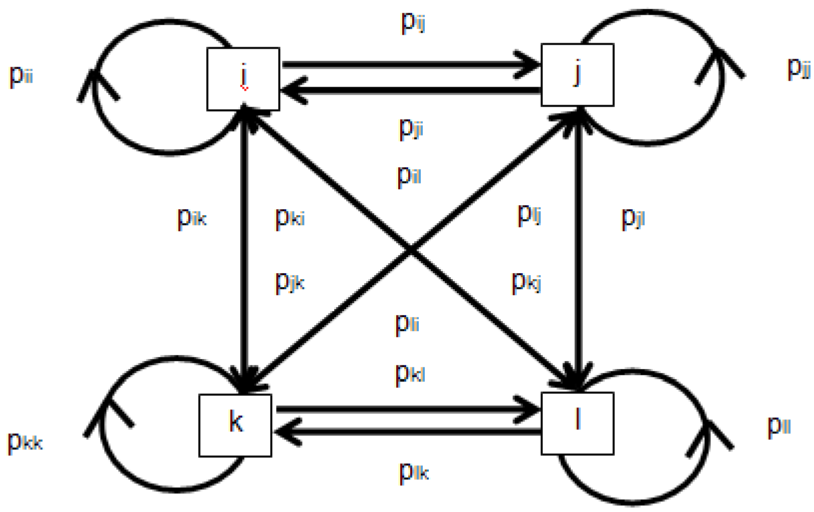


Figure 5.1 Transition diagram.

Traditionally, Markov chains have been used to estimate the probability of a machine breaking down after running for one full day or in marketing applications to study the 'brand switching' problem among customers (Idolor, 2010). More so in the area of finance, Markov chains have been used rather extensively. Niederhoffer and Osborne (1966) use Markovian properties to demonstrate the non-random behaviour in the transaction of ticker prices. McQueen and Thorley (1991) use Markov chains to examine the random walk hypothesis of stock prices and found that high returns had a tendency of trailing runs of low returns in their data set. Turner et al. (1989) use two-state Markov chains to estimate the variance of stock returns while Shiyun et al. (1999) introduce the use of Markov chains to study the Nikkei stock trading volatilities and intraday bid-ask spreads. Wozabal and Hochreiter (2012) propose the use of Markov chains for credit rating changes. Carmichael (2011) introduces the application of Markov chains as an alternative to capital investment appraisal where states are represented as different combinations of investment parameters (interest/discount rate, cash flows and investment life span).

5.2.4 Propositions

To investigate the behaviour and superiority of sustainability indices/company stocks that are highly valued in ESG, three propositions are conjectured:

Proposition P5.1: FTSE4Good Australia Index will exhibit homogeneity in price movement. The FTSE4Good Australia index is considered in terms of the vector-process Markov chains. For the individual-process Markov chains (analysis of individual stocks), it is expected that there would be a higher probability of stock prices rising above $0.1 of their 10-day moving average (one of the states defined for stock price movement).

Proposition P5.2: The probability of a positive percentage change in index value is higher for sustainability indices (FTSE4Good Australia Index, Dow Jones Stock Exchange Index, SSE180 Corporate Social Responsibility Index) compared to ordinary indices.

Proposition P5.3: There is a higher probability that the trading volume of company stocks (part of the FTSE4Good Australia Index) will be above 10% of their 10-day moving average (trading volume is used as an indicator to represent interest in a particular stock).

5.3 Results

The results are presented in three parts:

- Stock price behaviour
- Stock index behaviour
- Trading volume behaviour.

5.3.1 Stock price behaviour

Closing prices, for a 4-year period from 2008–2011, are obtained through authorised access to the Security Industry Research Centre of Asia Pacific (SIRCA). Any company stocks that are not part of the FTSE4Good Australia Index during this period are dropped off from the analysis. A total of 29 company stocks are analysed. Then, the 10-day moving average (see Gunasekarage and Power, 2001) is calculated. Figure 5.2 shows the plot of closing prices and the 10-day moving average for Company 1 in the year 2008. The difference between closing prices and the 10-day moving average (example shown in Figure 5.3) can be used to guide the development of states. A state with zero count is less helpful. Taking into account the distribution of price differences in the data set, four states (range given in parentheses) are selected as follows: 1 (≤ -$0.05); 2 (-$0.05, $0.05]; 3 ($0.05, $0.1]; and 4 (> $0.1). These states allow the labelling as to where each price difference actually falls into. Because each price difference is now labelled, the number of transitions from one state to the next can be counted.

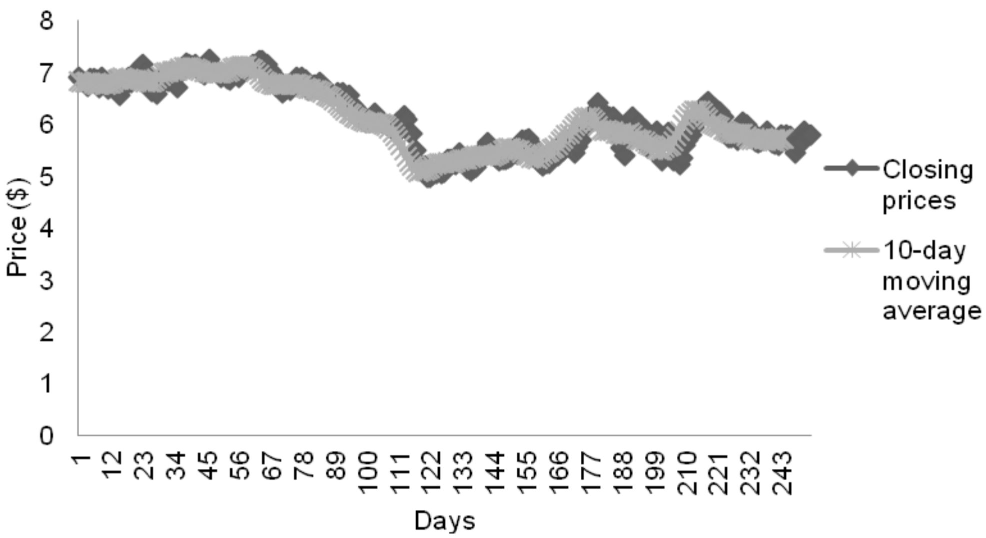


Figure 5.2 Closing prices and 10-day moving average for 2008 (Company 1)

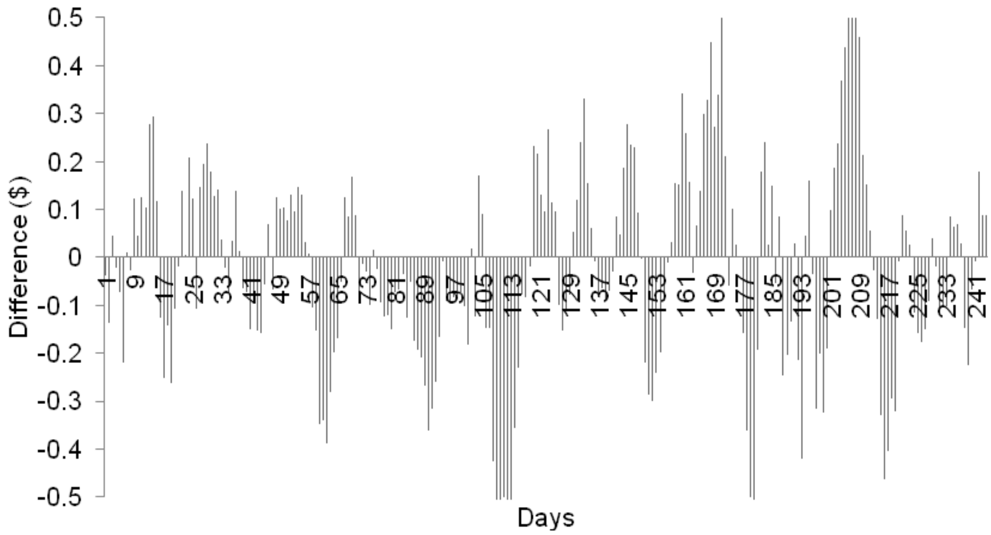


Figure 5.3 Difference between closing prices and 10-day moving average for 2008 (Company 1).

The transition matrix, **P**, consists of probabilities of moving from one state to another (transition probabilities). The states correspond to the rows and columns of the matrix. The transition probabilities, p_{ij}, can be calculated from counting the number of transitions between states and dividing by the total number of transitions. Once the transition matrix is established, the steady state probabilities can be found by balancing the inputs and outputs of each state given in Equations (5.3) and (5.4). The behaviour of stock price movement is considered for the whole FTSE4Good Australia Index in terms of the vector-process Markov chains, and for a single company stock in terms of the individual-process Markov chains.

Vector-process Markov chains

The test for homogeneity can be carried out after transition states are defined in the case of the vector-process Markov chains. According to Chakravarti et al. (1967), if a vector-process Markov chain is homogeneous, then $[X_t, t = 1, 2,...,T]$ can be reduced to individual-process Markov chains where $[X_{st}, t = 1,2,...T]$, $s = 1, 2,...,S$ has Markov chains with the same transition probabilities. Otherwise, if $\{X_t\}$ is not homogeneous, then $\{X_{st}\}$ must be studied separately as individual processes for each $s = 1, 2,...,S$ in order to make specific statements about the change in prices for the S different stocks (see Fielitz and Bhargava, 1973, p. 1188).

The total time interval can be divided into C equal subintervals. For each fixed i,j frequency matrix, elements f_{sc} can be formed easily, where f_{sc} equals the number of transitions of stock s from state i to state j during the c^{th} time interval for s = 1, 2,...,S and c = 1, 2,...,C. The statistic is computed as follows (Fielitz and Bhargava, 1973):

$$U_{ij}^{2} = \sum_{s,c}\left[f_{sc} - \left(\sum_{c} f_{sc} . \sum_{s} f_{sc}\right) / \left(\sum_{s,c} f_{sc}\right)\right]^{2} . \left[\left(\sum_{s,c} f_{sc}\right) / \left(\sum_{c} f_{sc} . \sum_{c} f_{sc}\right)\right] \quad (5.5)$$

Under the hypothesis of homogeneity, each statistic U_{ij}^{2} has an asymptotic distribution with (C-1) (S-1) as degrees of freedom.

To carry out this test, the daily price changes (for the period 2nd January 2008 till 30th December 2011) are divided into 4 subgroups in time, each consisting of 250 observations (because there is a total of 1004 daily observations for each stock). The last observation is omitted. Using the same notations, C = 4, S = 29, with 84 degrees of freedom.

Using the normal distribution table (with given z-values in Table 5.1), it is observed that the p-values are less than 0.05. Thus, the hypothesis for homogeneity should be rejected considering the number of significant observations obtained. The reason for non-homogeneity is most likely due to differences in magnitude between closing prices and the 10-day moving average which appear to vary from stock to stock.

(i,j)	U_{ij}^2	z-value*	Significance
1,1	9906.52	127.84	Sig (***)
1,2	2182.93	53.15	Sig (***)
1,3	1399.36	39.98	Sig (***)
1,4	2287.78	54.72	Sig (***)
2,1	1541.58	42.60	Sig (***)
2,2	16315.1	167.72	Sig (***)
2,3	2609.51	59.32	Sig (***)
2,4	1724.43	45.80	Sig (***)
3,1	1282.47	37.72	Sig (***)
3,2	2433.29	56.84	Sig (***)
3,3	2463.12	57.26	Sig (***)
3,4	1437.2	40.69	Sig (***)
4,1	1543.02	42.63	Sig (***)
4,2	2054.21	51.17	Sig (***)
4,3	950.59	30.68	Sig (***)
4,4	6981.29	105.24	Sig (***)

Table 5.1 Tests for homogeneity in vector-process Markov chains (* z-value from the normal distribution is calculated with the formula $z = \sqrt{2U^2} - \sqrt{2d-1}$ (after Fielitz and Bhargava, 1973); The normal distribution table may be used because the chi-square distribution is asymptotically normal for more than 30 degrees of freedom. *** significance of probabilities less than 0.05; U_{ij}^2 is the chi-square statistic; and d represents degrees of freedom.

Because heterogeneity is detected, what this implies is that the vector-process Markov chains would not be able to generalise or predict stock price movements and attention should instead shift towards a particular stock's Markov chain analysis.

Individual-process Markov chains

For the individual-process Markov chains (analysis of 29 individual company stocks which are part of the FTSE4Good Australia Index), the state probabilities are as shown in Table 5.2 based on Equations (5.1–5.4).

Stock	π_1	π_2	π_3	π_4
1	0.355	0.24	0.12	0.283
2	0.46	0.061	0.019	0.46
3	0.417	0.133	0.064	0.385
4	0.400	0.09	0.051	0.449
5	0.375	0.235	0.089	0.300
6	0.46	0.016	0.011	0.513
7	0.31	0.387	0.092	0.21
8	0.187	0.614	0.091	0.107
9	0.433	0.0745	0.0318	0.46
10	0.449	0.0487	0.0249	0.477
11	0.346	0.332	0.12	0.202
12	0.465	0.0348	0.015	0.485
13	0.462	0.135	0.0663	0.337
14	0.456	0.0456	0.0299	0.476
15	0.0485	0.889	0.0461	0.0156
16	0.497	0.062	0.0348	0.407
17	0.122	0.736	0.086	0.055
18	0.232	0.514	0.138	0.114
19	0.400	0.249	0.103	0.247
20	0.367	0.268	0.103	0.262
21	0.217	0.569	0.0954	0.118
22	0.279	0.424	0.133	0.163
23	0.398	0.153	0.085	0.363
24	0.271	0.392	0.128	0.208
25	0.5	0.0438	0.0229	0.432
26	0.1	0.888	0.039	0
27	0.0289	0.0484	0.0463	0.876
28	0.443	0.130	0.055	0.371
29	0.096	0.801	0.058	0.045

Table 5.2 Probability of stock price movement in FTSE4Good Australia Index (4 states; 10-day moving average).

For this empirical analysis, it is noted that the probability of falling into any of the four states appear to vary from one company stock to another. There is insufficient evidence to conclude that there is a higher probability that daily stock prices will beat its 10-day moving average by \$0.1. Hence, selecting a stock that is rated more highly in ESG may not necessarily lead to superior performance. A similar conclusion is observed in the following scenarios: analysis was extended to 5-day moving average; three states were selected instead of four states; price differences were calculated in the form of percentages (see Appendix K).

To check whether the transition probabilities of stock prices have stationary properties and to determine the order of the Markov chains, the test for stationarity and test for order are carried out on individual company stocks (Fielitz and Bhargava, 1973).

Test for stationarity

The null hypothesis is:

$$H_o : p_{ij}(t) = p_{ij}$$

whereas the alternative hypothesis is

$$H_a : p_{ij}(t) \text{ is dependent on } t$$

for all i,j = 1, 2,...V; t = 1, 2,...T

The chi-square statistic for stationarity is computed as follows (Fielitz and Bhargava, 1973; Idolor, 2010):

$$U_i^{\,2} = \sum_{t,j} \left(\left\{ [f_{ij}(t) / \sum_j f_{ij}(t)][\sum_j f_{ij}(t)] - [\sum_t f_{ij}(t) / \sum_j \sum_t f_{ij}(t)][\sum_j f_{ij}(t)] \right\}^2 / \left\{ [\sum_t f_{ij}(t) / \sum_j \sum_t f_{ij}(t)][\sum_j f_{ij}(t)] \right\} \right) \quad (5.6)$$

where f_{ij} (t) denotes the observed number of transitions from state i at time t-1 to state j at time t. Under the null hypothesis, each U_i^2 has an asymptotic chi-square distribution with (V-1) (T-1) degrees of freedom. As well, according to Fielitz and Bhargava (1973), U_i^2, for i = 1,2,...V are asymptotically independent, so that the sum

$$U^2 = \sum_i U_i^{\,2} \quad (5.7)$$

has an asymptotic chi-square distribution with V (V-1) (T-1). The normal distribution table may be used because the chi-square distribution is asymptotically normal for more than 30 degrees of freedom. Using the normal distribution table with 12036 degrees of freedom (4 x 3 x 1003 = 12036), there is insufficient evidence to reject the null hypothesis at a 95% confidence interval for all stocks analysed. This implies that the transition state probabilities for stock prices are stationary. The results presented in Table 5.2 are considered valid.

Test for order

The chi-square statistic for the test for order is given as (Fielitz and Bhargava, 1973):

$$U^2 = \sum_{i,j} \left(\left\{ \sum_t f_{ij}(t) - \left[\sum_j \sum_t f_{ij}(t) \sum_i \sum_t f_{ij}(t) \right] / \left[\sum_i \sum_j \sum_t f_{ij}(t) \right] \right\}^2 / \left[\sum_j \sum_t f_{ij}(t) \sum_i \sum_t f_{ij}(t) / \left[\sum_i \sum_j \sum_t f_{ij}(t) \right] \right] \right) \quad (5.8)$$

where f_{ij} (t) denotes the observed number of transitions from state i at time t-1 to state j at time t.

The null hypothesis (H_o) tested is:

H_o: A zero order Markov chain or independent trials sequence.

against the alternative hypothesis (H_a):

H_a: A first or higher order Markov chain dependent on the preceding state.

The statistic U^2 has an asymptotic chi-square distribution with $(V-1)^2$ degrees of freedom.

If the value of a particular state is found to be dependent not only on the previous state but also on the previous α ($\alpha > 1$) state, the model applied is said to be in the α^{th} order Markov chain (Anderson and Goodman, 1957). Using the chi-square distribution table with 9 degrees of freedom $[(4-1)^2 = 9]$; for all the individual stocks analysed, there is statistically significant evidence to reject the null hypothesis at a 95% confidence interval. This implies that the models correspond to first or higher order Markov chains.

5.3.2 Stock index behaviour

The second part of the empirical analysis involves predicting the stock index trend of the FTSE4Good Australia Index, DJSI and SSE180 Corporate Social Responsibility Index. Two random variables representing different states are defined:

$X_n = 1$, if percentage change in index value < 0 (note that the definition of states is different to that in section 5.3.1)

$X_n = 2$, if percentage change in index value > 0 (note that the definition of states is different to that in section 5.3.1)

Let the transition matrix be,

$$\mathbf{P} = \begin{bmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{bmatrix}$$

which consists of four transition probabilities ($p_{11}, p_{12}, p_{21}, p_{22}$). Similar to section 5.3.1, the transition probabilities are calculated from counting the number of transitions between states and dividing by the total number of transitions, to give a frequency.

The analysis of the FTSE4Good Australia Index daily data from 2nd January 2008 till 30th December 2011 yields the following transition matrix:

$$\mathbf{P} = \begin{bmatrix} 0.426 & 0.509 \\ 0.546 & 0.521 \end{bmatrix}$$

By solving Equation (5.3), the state probabilities are $\pi_1 = 0.48$ and $\pi_2 = 0.51$ respectively which means that there is a higher probability of a positive percentage change in index value for the FTSE4Good Australia Index.

Next, the DJSI monthly data is obtained from 31st August 1999 till 30th April 2012. Its transition matrix is as shown:

$$\mathbf{P} = \begin{bmatrix} 0.507 & 0.493 \\ 0.393 & 0.607 \end{bmatrix}$$

From Equation (5.3), the state probabilities are found to be $\pi_1 = 0.44$ and $\pi_2 = 0.56$.

When the SSE180 Corporate Social Responsibility Index daily data was examined for the period 5th August 2010 till 2nd May 2012, the following transition matrix is obtained:

$$\mathbf{P} = \begin{bmatrix} 0.5 & 0.5 \\ 0.49 & 0.51 \end{bmatrix}$$

This yielded nearly equal state probabilities where $\pi_1 = 0.49$ and $\pi_2 = 0.501$. As a result, P5.2 is accepted on the basis that sustainability indices (FTSE4Good Australia Index, DJSI, SSE180 Corporate Social Responsibility Index) appear to have a higher probability of experiencing a positive percentage change.

Based on the test for stationarity and test for order (Fielitz and Bhargava, 1973) given in Equations (5.6) and (5.8), the Markov chains for all sustainability indices (FTSE4Good Australia Index, DJSI, SSE180 Corporate Responsibility Index) correspond to a first or higher order and the transition probabilities are found to be stationary at a 95% confidence interval.

Other SSE indices' daily data are also examined and the results are tabulated in Table 5.3. By comparison, these results appear to indicate that there is a higher probability of stock index falling into a decreasing state which might suggest that sustainability indices are better in the long run. The tests of stationarity and order based on Equations (5.6) and (5.8) are also conducted and reported in Table 5.3.

SSE Indices	π_1	π_2	Test for stationarity	Test for Order
SSE180 Transportation	0.502	0.498	Stationary	First or Higher Order
SSE180 Infrastructure	0.51	0.48	Stationary	First or Higher Order
SSE50	0.51	0.48	Stationary	First or Higher Order
SSE380	0.50	0.49	Stationary	First or Higher Order

Table 5.3 Probability of SSE stock indices movement.

5.3.3 Trading volume behaviour

The difference between daily trading volume and its 10-day moving average (in percentage) is used to create the states here. For this section, the four states: 1 (≤ -5%); 2 (-5%, 5%]; 3 (5%, 10%]; and 4 (> 10%) are defined differently to that in sections 5.3.1 and 5.3.2. The data set selected for this study consists of 29 company stocks which are part of the FTSE4Good Australia Index from 2nd January 2008 till 30th December 2011. In order for P5.3 to be accepted, the probability of π_4 has to be larger than the probability of other states (π_1, π_2 and π_3). The results are outlined in Table 5.4.

Stock	π_1	π_2	π_3	π_4
1	0.5	0.104	0.057	0.34
2	0.5	0.115	0.06	0.325
3	0.512	0.113	0.0401	0.334
4	0.51	0.107	0.053	0.33
5	0.539	0.096	0.045	0.317
6	0.533	0.104	0.0308	0.332
7	0.517	0.093	0.05	0.34
8	0.553	0.075	0.045	0.328
9	0.50	0.113	0.039	0.346
10	0.51	0.097	0.06	0.331
11	0.50	0.105	0.043	0.35
12	0.493	0.132	0.039	0.336
13	0.5	0.100	0.049	0.35
14	0.483	0.132	0.0586	0.326
15	0.533	0.102	0.145	0.219
16	0.518	0.114	0.0378	0.329
17	0.524	0.075	0.044	0.357
18	0.52	0.0975	0.0478	0.332
19	0.51	0.112	0.044	0.324
20	0.531	0.10	0.037	0.33
21	0.544	0.0727	0.0378	0.345
22	0.518	0.108	0.0418	0.333
23	0.551	0.09	0.0467	0.312
24	0.53	0.075	0.038	0.348
25	0.517	0.0993	0.0467	0.336
26	0.555	0.0849	0.0359	0.324
27	0.138	0.0378	0.0132	0.81
28	0.523	0.102	0.0418	0.332
29	0.512	0.093	0.0331	0.356

Table 5.4 Probability of trading volume movement for FTSE4Good Australia Index.

These results suggest that for all 29 company stocks which are part of FTSE4Good Australia Index, the probability of being in state 1 (≤ -5%) is the highest. This implies that there is a higher likelihood of stock volume trading below 5% of its 10-day moving average. In a similar fashion, the test for stationarity and test for order (after Fielitz and Bhargava, 1973) are applied here.

The transition probabilities are found to be stationary at a 95% confidence interval for all individual stocks (using the normal distribution table with 12036 degrees of freedom). The normal distribution table may be used for the test for stationarity because the chi-square distribution is asymptotically normal for more than 30 degrees of freedom.

Based on the test for order (using the chi-square distribution table with 9 degrees of freedom), the claim that observations at successive periods are statistically independent is rejected at a 95% confidence interval. Therefore, the models correspond to first or higher order Markov chains.

5.4 Discussion

Several implications arise from this work. Firstly, empirical results for the vector-process Markov chains suggest that price movements among company stocks that are part of the FTSE4Good Australia Index are heterogeneous. Therefore, the vector-process Markov chains would not be able to generalise or predict the dynamics of price movements convincingly. While it is anticipated that companies which are highly valued in ESG and included in a similar sustainability index may demonstrate homogeneity in price movement, this is proven to be false.

The effect of heterogeneity among stocks is amplified as information concerning different companies becomes available at various times. This deduction is tested by analysing data from RepRisk (RepRisk, 2013) which measures the intensity of bad news for companies (also known as public pressure index) on a monthly basis. RepRisk (2013) searches for news in over 13 languages across thousands of sources. The results from the analysis of sample US and Australian companies (see Appendix L) confirm that the intensity of bad news differs among companies across a given period. The ‘short-termism’ approach of investors (Tobing et al., 2011) could also exacerbate the situation. If this is true, then investors are expected to react momentarily (buy or sell stocks) due to the effects of information asymmetry (exposure to company news is different among investors at different points in time). In turn, this contributes to the non-homogeneous behaviour among stocks.

The behaviour of stock price movement is then considered for individual company stocks. All individual-process Markov chains (29 company stocks) are found to be of the first or higher order and transition probabilities are stationary. This implies that the transition probabilities are time independent. Evidence against the random walk hypothesis (see Godfrey et al., 1964) is found and this conflicts with the finding of Fielitz and Bhargava (1973) when 200 stocks in the NYSE were analysed. Price movement for individual stocks can be predicted using Markov chains. However, results show that there is insufficient evidence to conclude that these stocks have superior performance.

One reason advanced for this is that the perception of companies' ESG performance among stakeholders may vary. This could be made worse by companies selecting to report only on sustainability criteria that are most favourable to them. The lack of standard criteria in turn may make it difficult for investors to compare and distinguish the ESG performance between companies which directly affects their investment making decision (to buy or sell stocks).

Also, it is found that all of the sustainability indices analysed (FTSE4Good Australia Index, DJSI, SSE Corporate Social Responsibility Index) in this chapter have a marginally higher probability of experiencing a positive percentage change. This possibly suggests that it might be worthwhile investing in sustainability indices as opposed to individual company stocks. The transition probabilities for all indices are found to be stationary.

5.5 Conclusion

This study uses Markov chains to predict the behaviour (price movement, index and trading volume) of the FTSE4Good Australia Index and its constituents. From the results, P5.1 is rejected. Price movement among company stocks of the same index is non-homogeneous. There is also no clear indication that there is a higher probability of individual stock prices (company stocks that are part of the FTSE4Good Australia Index) rising above the 10-day moving average by $0.1.

Generally, four states are selected to carry out the analysis in this chapter. It should be noted that the increments in the number of states need not be constant and this can vary at the discretion of the analysts. Finer subdivisions will give more states while coarser subdivisions will lead to fewer states. In this case, it is not possible to demonstrate all variations on the transition diagrams. Sensitivity analysis was conducted by altering the number of transition states but this appears to have little impact on the conclusions obtained (see Appendix K).

From the remaining empirical results of this study, P5.2 is marginally accepted while P5.3 is rejected. The analysis of stock index trend demonstrates that there is a higher probability of sustainability indices moving in an increasing trend but only marginally. However, there is insufficient evidence to conclude that the trading volume of stocks (part of the FTSE4Good Australia Index) will be above 10% of its 10-day moving average.

CHAPTER 6 – EXAMINING THE EFFECTIVENESS OF BUILDING SRTs

6.1 Introduction

Buildings regarded or classed as sustainable receive recognition or an award from an SRT provider (Siew et al., 2013). (The terminology ‘sustainable building’ is used in this chapter to refer to building that receives recognition or an award from an SRT; and ‘non-sustainable building’ as all other buildings).

Commentators, however, are not in agreement on the benefits of sustainable buildings. Some argue that sustainable buildings are often associated with positive impacts such as increased productivity (Ries et al., 2006; Heerwagen, 2000), higher rental differentials (Miller et al., 2008; Fuerst and McAllister, 2008) and better occupancy rate (Wiley et al., 2010). As a result, property investors have started relying on SRT awards in their investment decision making. In contrast, other commentators have highlighted deficiencies in building SRTs such as the existence of point-hunting (Chew and Das, 2007; Fard, 2012; Fenner and Ryce, 2008; Siew et al., 2013), use of non-scientific benchmarks (Siew et al., 2013) and the absence of occupant performance criteria (Baird, 2009).

Much commentary on building SRTs is anecdotal. There is a lack of empirical research investigating their effectiveness. This chapter aims to address the gap in the literature by exploring the effectiveness of building SRTs. If building SRTs are to be effective, it is anticipated that:

I. The variation in scores or criteria weights (within each SRT) across different users would be minimal. In Chapters 2 and 3, it is established that a majority of SRTs have adopted deterministic criteria scores and weights while neglecting the need to account for uncertainty. This chapter demonstrates whether such an approach is justified.

II. Occupant’s satisfaction levels in sustainable buildings would be higher than those for non-sustainable buildings.

III. There would be consistency (within each SRT) in scores for buildings with similar awards. Anecdotal evidence suggest that users mostly rely on the final sustainability award given by building SRTs in deciding how ‘green’ a building is without scrutinising the underlying criteria scores. It is therefore important to investigate the level of consistency of criteria scores for buildings with similar sustainability awards.

To find contrary to that anticipated may indicate deficiencies within current SRTs. And this in turn would imply that users of SRT information, such as property investors, could potentially be making decisions on flawed information. Extra care would be needed in interpreting the outcomes of SRTs.

The remainder of this chapter is organised as follows. First, some necessary background literature is provided. A description of the data collection method employed and type of respondents engaged are then given. The results are presented in three sections: section 6.4.1 – Uncertainty analysis; section 6.4.2 – Post-occupancy evaluation; section 6.4.3 – Characteristics of sustainability awards.

6.2 Background

Uncertainty analysis

Alsulami and Mohamed (2010) maintain that uncertainty arises because of factors such as inadequate data, measurement error, subjective judgement and ambiguity. They argue that because sustainability is related to the future, sustainability performance should be considered for conditions of uncertainty. However, the current SRTs do not acknowledge uncertainty, thereby reducing the transparency of their underlying assumptions. Ignoring uncertainty in value judgements alters any ranking of ‘alternatives’ (Hyde et al., 2004).

This chapter investigates the degree of variation that exists in both criteria scores and weights (within each SRT) across different users. The following two propositions are examined:

Proposition P6.1: There is no variation in criteria scores and weights (within each SRT), across different users.

Proposition P6.2: There is no difference in scoring deterministically or in scoring that allows for variability within an SRT.

Post-occupancy evaluation

Most SRTs neglect the need to account for building occupancy performance. Baird (2009, p. 1070) argues for the incorporation of occupant performance criteria as a key ingredient in making progress towards truly sustainable buildings, claiming that 'buildings that perform poorly from the occupants' point of view are unlikely to ever be sustainable'.

Recognising this importance, the interaction between occupants and their buildings has been studied in terms of thermal comfort (Nicol and Roaf, 2005; Pfafferott et al., 2007; Gossauer and Wagner, 2007; Kavgic et al., 2008; Wagner et al., 2007), air quality (Kavgic et al., 2008; Macher et al., 1991), acoustic quality (Lee, 2010; Jensen and Aren, 2005) and building layout (Chilton and Baldry, 1997). A post-occupancy evaluation was conducted by Liu (1999) to gauge the satisfaction levels of occupants in a selected residential community in Hong Kong. Leaman and Bordass (2001) assess the occupant surveys relating to Probe (see Cohen et al., 2001) and find that comfort, health and productivity are positively associated.

However, these studies generally fail to contrast building occupants' satisfaction levels between a sustainable building and a non-sustainable building. Examining post-occupancy survey results on sustainable buildings alone does not answer the question of whether a distinguishable value actually exists in having an SRT award. The study advanced in this chapter departs from other literature by comparing and contrasting occupants' satisfaction levels across both sustainable building and non-sustainable building with similar functions.

Given claims made about the benefits of sustainable buildings (see Ries et al., 2006; Wiley et al., 2010; Miller et al., 2008; Fuerst and McAllister, 2008), the following proposition is examined:

Proposition P6.3: Occupants' satisfaction levels are expected to be higher in a sustainable building compared to a non-sustainable building.

Characteristics of sustainability awards

Each SRT has a unique set of sustainability awards (see Siew et al., 2013). For example, the award categories for LEED in progressive order, are Certified, Silver, Gold and Platinum while the award categories for BREEAM, also in progressive order, are Unclassified, Pass, Good, Very Good, Excellent and Outstanding. Within each SRT, it is unknown whether there is consistent interpretation of the level or category of sustainability for buildings that have attained similar sustainability awards. Although anecdotal evidence seems to suggest otherwise, this has not been proven empirically. The fourth proposition is examined:

Proposition P6.4: Within an SRT, criteria scores are consistent for projects with similar sustainability awards.

6.3 Data and research methods

Data for sections 6.4.1 and 6.4.2 of the study are obtained from an experiment. The analytic hierarchy process (AHP) is used to derive the weightings for criteria. Data for section 6.4.3 is from the LEED database (USGBC, 2013).

Uncertainty analysis

A survey was designed to gauge occupant's/user's perception on the performance of a range of completed buildings selected with a range of sustainability awards obtained (see Appendix M). The experiment involved seeking responses to a range of questions on: building management; design for indoor environment, energy consumption, emission reduction, use of 'green' materials; environmental impact reduction effort; and design innovation. Responses were given in terms of optimistic, most likely and pessimistic answers. Note that some SRTs, such as Green Star, cover different building phases, namely design, as-built and actual building performance (GBCA, 2013a). The seven buildings selected for this experimental study are referred to with letters A to G. The award and respective building SRT (in parentheses) for these buildings are: A (6 Green Star); B (6 Green Star); C (4 Green Star); D (5 Green Star); E (5 Green Star); F (Outstanding – BREEAM); G (Very Good – BREEAM).

Respondents were initially given a project brief (see GBCA 2012c; BREEAM, 2013) detailing the characteristics of each of these seven buildings and asked to assess building performance across different criteria as outlined in Table 6.1.

Building SRT	Criteria
Buildings assessed with Green Star	Quality of project management (PM); indoor environmental quality (IEQ); energy consumption (Energy); design of building to reduce emission (Emissions); the use of 'green' materials in the building design ('Green' Materials).
Buildings assessed with BREEAM	Effort put into the design to reduce environmental impact (EI); level of design innovation of the building (INV).

Table 6.1 Building criteria (see Appendix M)

The scoring is based on an interval scale (see Carmichael, 2013) from 1 (worst) to 10 (best). For each criterion, respondents were requested to first provide a deterministic score, and then (a) optimistic, (b) most likely and (c) pessimistic scores. From the last three scores, the mean = (a+4b+c)/6, and variance = $[(c\text{-}a)/6]^2$ follow (Cottrell, 1999, Carmichael, 2006; Carmichael and Balatbat, 2008). A total of 122 responses were obtained.

The Analytic Hierarchy Process (AHP). AHP is one of the many ways to establish criteria weights based on inputs from stakeholders. The advantage of AHP is its ability to handle both qualitative and quantitative data in a robust but simple structure. It also reduces subjectivity and produces decisions based on consistent judgements (Saaty, 1980). To establish criteria weights, a set of pairwise comparison matrices is created where the relative importance of each of the criteria is compared against each other using Saaty's (1990) predefined scale. 52 respondents were randomly selected out of the initial 122 respondents to rate the relative importance of nine criteria: emissions (E); energy (ENE); water (W); land use and ecology (LUE); indoor environmental quality (IEQ); transport (T); materials (MAT); management (MGT); and innovation (INV) for a university building in Sydney (5 storeys; 15,000 m^2).

Consistency in value judgements can be established using a consistency ratio (CR) (Saaty, 1977, 1980, 1990, 1994; Triantaphyllou and Mann, 1995; Coyle, 2004). CR is obtained by dividing the Consistency Index (CI) with the Random Consistency Index (RI) via the following equation:

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \tag{6.1}$$

where CI is given by

$$\mathrm{CI} = (\lambda_{max} - \mathrm{n})/(\mathrm{n} - 1) \tag{6.2}$$

where λ_{max} is the principal eigenvalue of the matrix (see Saaty, 1980; Triantaphyllou and Mann, 1995 for details) and n is the size of the comparison matrix.

RI is calculated by averaging the eigenvalue of randomly generated matrices using the rating scale of Saaty (Saaty, 1990). For the analysis in this chapter, the RI value of 1.45 (for n = 9) derived from a sample of 500 randomly generated matrices is taken from

Triantaphyllou and Mann (1995). Researchers (Coyle, 2004; Saaty, 1980; Triantaphyllou and Mann, 1995) recommend that CR should not be in excess of 0.1.

Post-occupancy evaluation

An occupant indoor environmental quality (IEQ) survey originally developed by the Centre for the Built Environment (CBE), University of California Berkeley is used to compare occupant satisfaction in sustainable and non-sustainable buildings. The CBE survey consisted of ten sections – occupant's background, personal workspace location, personal workspace description, building layout, building furnishings, thermal comfort, air quality, lighting, acoustic quality, building features and general comments (Centre for the Built Environment, 2010). Questions concerning occupants' satisfaction levels and how some of the criteria (building layout, thermal comfort, air quality, lighting, acoustic quality) enhances or interferes with their ability to get their jobs done are posed. The primary advantage of using this survey is that the questions developed have been extensively tested (Zagreus et al., 2004) and deemed to be suitable for data gathering. Huizenga et al. (2002) claim that this survey has been pre-tested with a method known as 'cognitive interviewing', which assesses how well respondents are able to comprehend and accurately report answers to survey questions. While most of the original questions in the survey were maintained, modification was carried out in order to account for uncertainty, by introducing optimistic/most likely/pessimistic scores. Questions on personal workspace location, building furnishings and general comments were removed to minimise the time needed to fill up the survey. The original scale used by the CBE from 1 (very dissatisfied) to 7 (very satisfied) was maintained.

For the experimental study, building X (5 storeys;15,000 m^2; 6 stars – Green Star) is chosen as representative of a sustainable building whereas building Y (4 storeys; 9,500 m^2) is deemed to be a non-sustainable building as it received no certification from any building SRTs. The average emissions from building Y is reported to be 16.1% higher than the benchmark of all university buildings on campus between September 2012 to June 2013 (GreenSense, 2013). These two buildings were located adjacent to each other, and were also comparable in terms of their function as a space for learning and teaching. Responses were requested only from the occupants of both these buildings.

51 responses were gathered for building X. Of the 51 respondents, 27.5% have identified the nature of their work as professional, 62.7% as technical and the remaining 9.8% as other. In terms of the number of hours spent in their respective workspaces, 31.3% indicated that they spend 10 hours or less per week, 11.8% indicated that they spend between 11 to 30 hours per week while 56.9% indicated that they spend 30 hours or more per week.

68 responses were gathered for building Y. 16.2% identified the nature of their work as professional, 10.2% as technical, and 73.5% as other. Of the 68 respondents, 88.2% spent 30 hours or more per week in their workspaces, 7.4% spent between 11 to 30 hours, while 4.4% spent 10 hours or less per week.

Characteristics of sustainability awards

Criteria scores were obtained for 433 LEED new construction projects (USGBC, 2013) spanning across four sustainability awards (Certified, Silver, Gold and Platinum). Boxplot analysis was carried out as it allows for a visual comparison of the level, spread and symmetry of the data distribution (Williamson et al., 1989). From this analysis, it is possible to make conclusions on the consistency in criteria scores for projects with similar sustainability awards.

6.4 Results

The results are discussed in three sections: variation in criteria scores and weights; occupants' satisfaction levels; and characteristics of sustainability awards.

6.4.1 Variation in criteria scores and weights

Variation in criteria scores

Figures 6.1a to 6.1d show the cumulative frequency distribution of the different criteria scores (PM, IEQ, Energy, Emissions, Green Materials, EI, INV) for buildings A, B, C and D. From the overall analysis of the results (see Figures 6.1 and Appendix N), variation in scores is observed for different sustainability criteria (some more prominent than others) even though similar project briefs (GBCA 2012c; BREEAM, 2013) were given to respondents. N is the total number of respondents. Proposition P6.1 is not supported; rather these results point to the need for measurements in terms of a central tendency and dispersion. Also, based on a paired sample t-test for building A (see Appendix P), a statistically significant difference (p-value < 0.01) is found between deterministic scores and scoring which allows for uncertainty in value judgements. This finding is consistent for a majority of sustainability criteria across all buildings (A to G). Hence, proposition P6.2 is rejected. This implies that the use of deterministic scores in SRTs to assess sustainability performance is questionable.

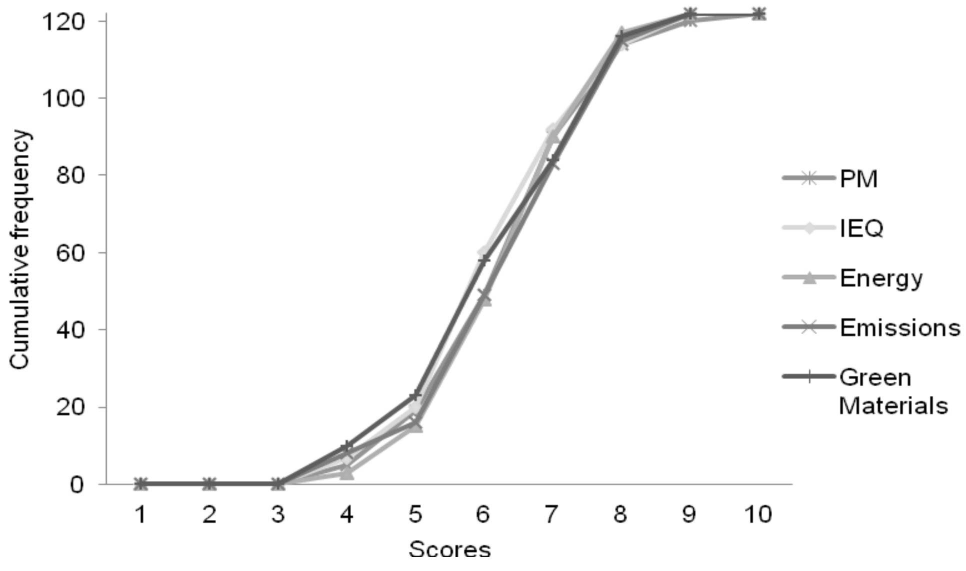


Figure 6.1a Experimental results – Building A, N = 122.

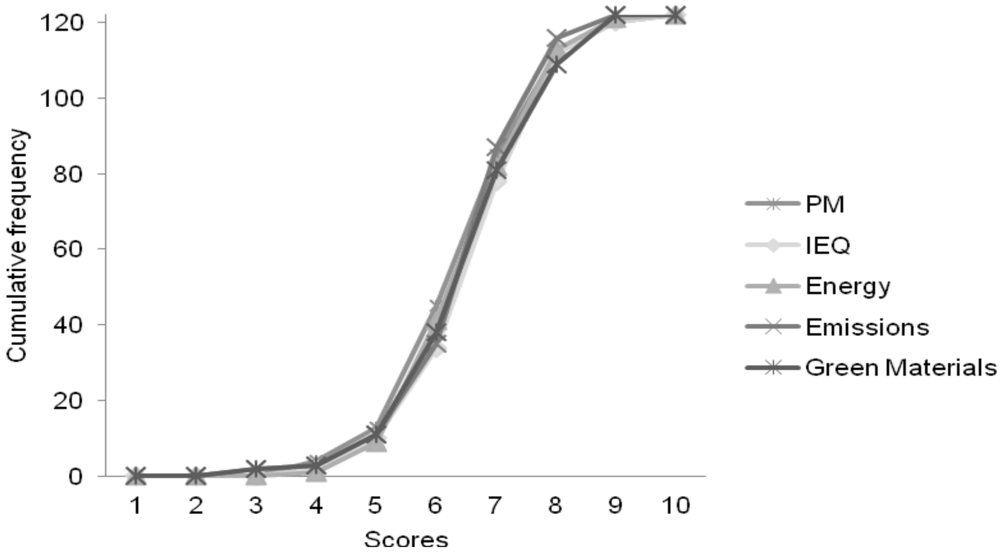


Figure 6.1b Experimental results – Building B, N = 122.

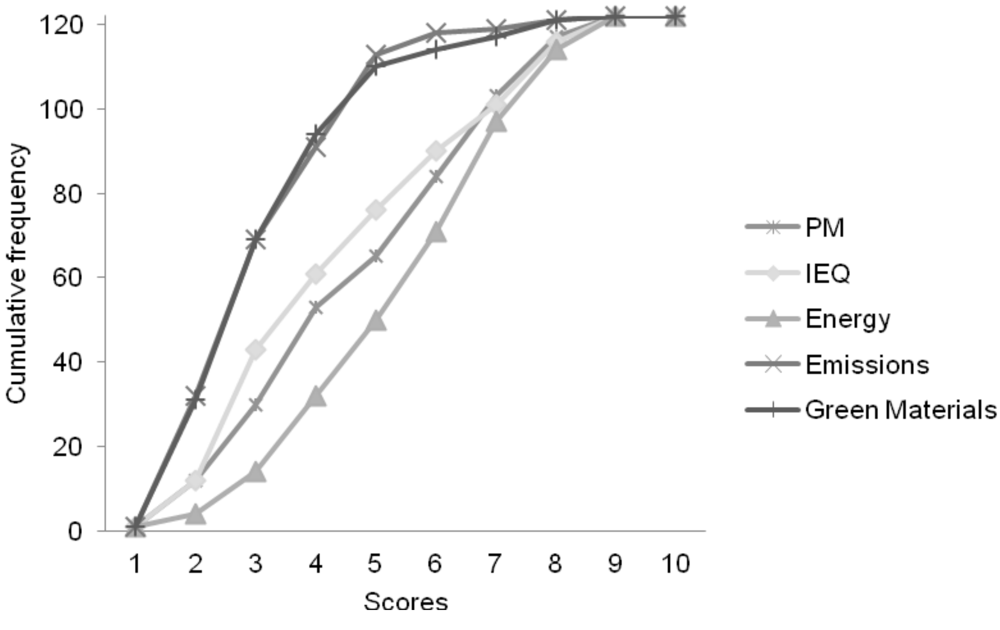


Figure 6.1c Experimental results – Building C, N = 122.

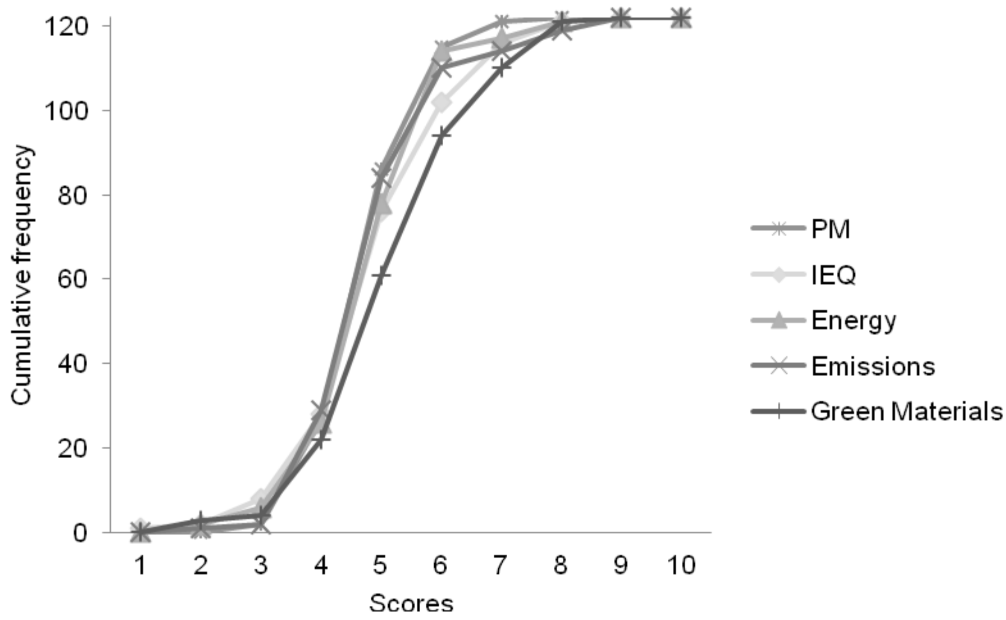


Figure 6.1d Experimental results – Building D, N = 122.

Variation in criteria weights

A case example of pairwise comparison (from one of the respondents) is given in Table 6.2. When a criterion is compared with itself, a value of 1 is assigned signifying equal importance. Of the 81 entries, 9 self-comparisons on the diagonal matrix are given values of 1. Half of the remainder are reciprocals by virtue of the inverted comparisons. Therefore, each respondent only has to provide value judgements for 36 pair-wise comparisons instead of 81.

	E	ENE	W	LUE	IEQ	T	MAT	MGT	INV	Weights
E	1	7	7	7	7	7	7	7	7	0.387
ENE	1/7	1	5	7	7	7	7	7	7	0.254
W	1/7	1/5	1	1	3	3	3	3	3	0.089
LUE	1/7	1/7	1	1	3	3	3	3	3	0.089
IEQ	1/7	1/7	1/3	1/3	1	1	1	1	1	0.035
T	1/7	1/7	1/3	1/3	1	1	1	1	1	0.035
MAT	1/7	1/7	1/3	1/3	1	1	1	1	1	0.035
MGT	1/7	1/7	1/3	1/3	1	1	1	1	1	0.035
INV	1/7	1/7	1/3	1/3	1	1	1	1	1	0.035

Table 6.2 Comparison matrix of sustainability criteria (CR = 0.055).

The criteria weights are the normalised principal eigenvector of the comparison matrix which can be calculated through the use of an excel spreadsheet (see Saaty, 1980). The total weights sum to 1. The consistency ratio (CR) for this particular matrix is 0.055 (less than 0.1) implying that value judgements are consistent.

For this exampled respondent, based on the weights, the most important criterion is E followed by ENE. W and LUE are perceived as having equal importance but more important than IEQ, T, MAT, MGT and INV. From Appendix Q, it is seen that variations in criteria weights exist, and depend on the perspective of the respondents. As such, variations in criteria weights need to be accounted for in building sustainability assessments.

6.4.2 Occupants' satisfaction levels

The results of the occupant satisfaction survey (in terms of means and standard deviations) are presented in Table 6.3, based on criteria influencing satisfaction levels, namely: building layout; thermal comfort; air quality; lighting; and acoustic quality. Scores above 4 indicate that occupants are satisfied, whereas scores below 4 suggest that occupants are dissatisfied.

Building layout

Questions about building layout include how satisfied the respondents are with the amount of space available for individual work and storage, level of visual privacy, ease of interaction with co-workers and whether the building layout enhances or interferes with their ability to do their work. Table 6.3 shows a slight difference in occupant satisfaction of building layout between X and Y. Occupants of building X claim to have the highest satisfaction (average scores given in parentheses) in terms of 'visual privacy' (5.06) followed by amount of space available for individuals (4.86), and ease of interaction with co-workers (4.84). Occupants of building Y are most satisfied with ease of interaction with co-workers (5.20). This is followed by 'visual privacy' (5.19), and amount of space available for individuals (5.07). The average score given by respondents when asked whether the building layout enhances their ability to carry out their work is slightly higher for Y (4.84) compared to X (4.52).

Thermal comfort

Respondents were asked of their level of satisfaction with the temperature in their workspace, and whether thermal comfort in their workspace enhances or interferes with their ability to do their work. Based on Table 6.3, occupants in building Y appear to demonstrate a slightly higher satisfaction level with thermal comfort (5.17) compared to occupants of X (4.82). The average score given by respondents when asked whether the thermal comfort enhances their ability to carry out their work is also slightly higher for Y (4.56) compared to X (4.14).

Air quality

Responses to how satisfied occupants are with air quality and whether air quality in their workspace enhances or interferes with their work are given in Table 6.3, which shows again that the satisfaction level in terms of air quality is higher for occupants in Y (5.34) compared to X (4.76). Occupants in Y also indicated that the air quality in their workspace enhances their ability to do their work (4.77) compared to occupants in X (4.35).

Lighting

Lighting questions focussed on occupants' satisfaction levels with amount of light, visual comfort, and whether lighting quality enhances or interferes with their ability to do their work. Building occupants in X had slightly lower satisfaction levels with the amount of light (4.69) compared to occupants in Y (5.20). A similar trend was noted for visual comfort: X (4.67) and Y (5.13). Most respondents indicated that lighting quality enhances their ability to do their work: X (4.01) and Y (4.74). Overall, occupants in both buildings were satisfied with the lighting quality.

Acoustic quality

Respondents were asked about noise level and sound privacy in their workspaces, and whether it enhances or interferes with their ability to do their work. From the results obtained, it appears that occupants in both buildings (X and Y) are dissatisfied with the acoustic quality. The average satisfaction score for noise level at building X was only 3.61 whereas building Y achieved a score of 3.60. Occupants were also dissatisfied with the sound privacy in X (3.60) and Y (3.75). Based on the results, there is an indication from occupants of both buildings that the acoustic quality interfered with their ability to do their work (both achieving an average score below 4).

The overall results here do not seem to demonstrate clearly that occupants' satisfaction levels are higher in a sustainable building compared to a non-sustainable building. Therefore, proposition P6.3 is not accepted.

Criterion	X (Sustainable building)		Y (Non-sustainable building)	
Building layout	Mean	Std	Mean	Std
Space	4.86	0.37	5.07	0.37
Visual	5.06	0.37	5.19	0.37
Interaction	4.84	0.36	5.20	0.36
Enhances ability to carry out work	4.52	0.35	4.84	0.33
Thermal comfort				
Temperature (Thermal comfort)	4.82	0.36	5.17	0.36
Enhances ability to carry out work	4.14	0.35	4.56	0.39
Air quality				
Air	4.76	0.36	5.34	0.33
Enhances ability to carry out work	4.35	0.37	4.77	0.32
Lighting				
Light	4.69	0.37	5.20	0.35
Visual comfort	4.67	0.39	5.13	0.35
Enhances ability to carry out work	4.01	0.35	4.74	0.35
Acoustic quality				
Noise level	3.61	0.28	3.60	0.33
Sound privacy	3.60	0.32	3.75	0.33
Enhances ability to carry out work	3.23	0.35	3.39	0.28

Table 6.3 Occupants' satisfaction levels with buildings X and Y.

6.4.3 Characteristics of sustainability awards

Figure 6.2 shows an example of four boxplots for the Sustainable site (SS) criterion across different LEED sustainability awards (Certified, Silver, Gold and Platinum). The vertical axis refers to the scores of the SS criterion while the horizontal axis shows the different sustainability awards. The box itself represents 50% of the scores for a particular sustainability award. The horizontal line in the middle of the box represents the median value of the SS criterion. The upper and lower ends of the boxes represent the hinges (upper end – upper quartile; lower end - lower quartile). The vertical lines protruding out of the boxes connect extreme scores (minimum and maximum scores) to the hinges (Williamson et al., 1989). From Figure 6.2, it is observed that the range of scores (in parentheses) for the SS criterion is large: Certified (1,12); Silver (4,11); Gold (4,12); Platinum (7,13). This implies that even though two projects assessed with a similar LEED framework have attained Certified awards, it could be that one project has gained a substantially higher score for the SS criterion (12) while the other has performed badly in SS (1), the latter improving its overall score through using other available criteria.

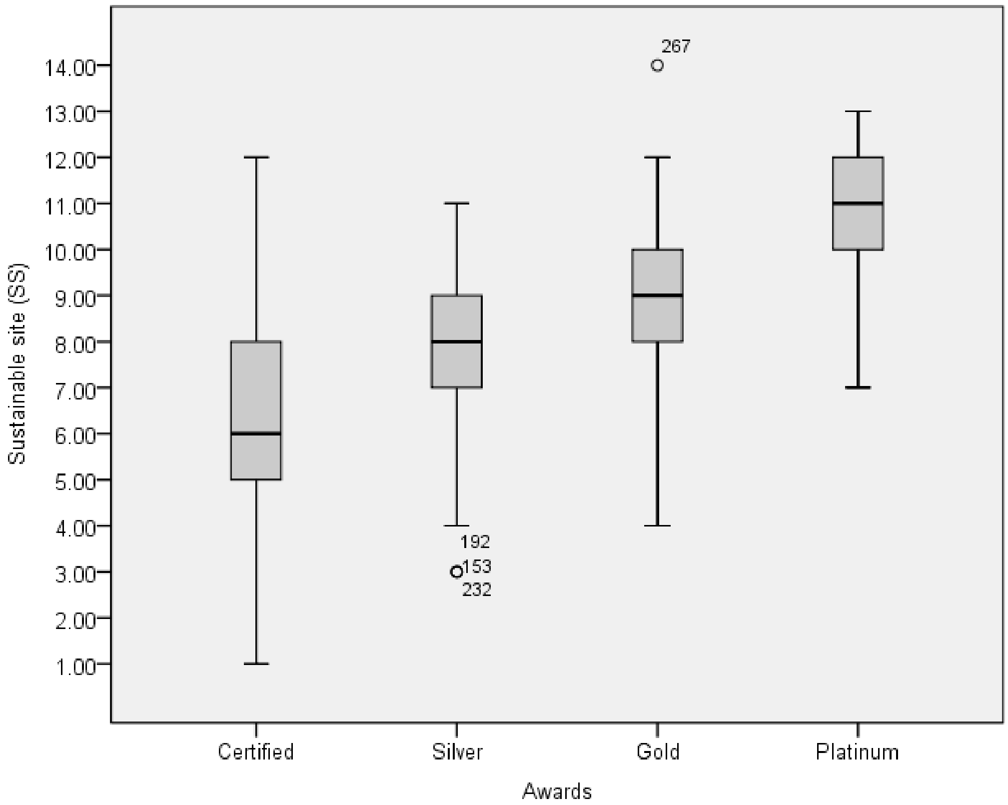


Figure 6.2 Boxplots of four LEED awards (Certified, Silver, Gold and Platinum) based on the Sustainable site (SS) criterion. The round symbols and numbers represent outliers and the data points respectively (see Williamson et al., 1989)

An examination of the remaining LEED data with boxplot analysis (Appendix O – similarly on the criteria of water , material, indoor environmental quality and innovation) reveals that the range of other criteria scores are large for projects with similar sustainability awards (Certified, Silver, Gold and Platinum).

Table 6.4 gives further details of the average scores earned out of the total available scores (in percentages) and the standard deviation. The results from this analysis suggest that:

- The average scores earned out of the total available scores for the Energy criterion is low (below 50%) for both Certified and Silver awards, and marginally exceeds the 50% mark for the Gold award.
- Although the Material criterion has a number of scores available, the average scores earned out of the total available scores (in percentages) are below 50% for Certified, Silver and Gold awards and slightly exceeds the 50% mark for the Platinum award.
- The standard deviation of scores earned over total available scores is high even within the same sustainability award.

The results here suggest that buildings with similar sustainability awards may not necessarily have the same standards of performance. It follows that proposition P6.4 is rejected.

Criterion	Certified	Silver	Gold	Platinum
Sustainable site (SS) (%)	45.4	54.3	61.3	77.7
	13.7	13.4	13.7	9.95
Water (W) (%)	55.7	63.6	68.8	76.9
	20.95	17.14	15.9	16.58
Energy (E) (%)	26.9	35	51.3	88.6
	13.27	15.91	19.37	9.76
Material (M) (%)	29.2	39.07	42.8	51.4
	14.3	12.69	9.67	9.6
Indoor environmental quality (IEQ) (%)	51.63	61.3	72	85.6
	11.6	13.02	13.03	8.92
Innovation (INV)	61.7	78.4	88	98.2
	28.3	22.1	18.2	5.66

Table 6.4. Summary of scores obtained as a percentage of total possible scores, across different criteria (upper value: average; lower value: standard deviation).

6.5 Implications

A number of implications arise from the findings of this chapter's exploratory study.

Implication (i). Variation in criteria scores and weights exists in the assessment of buildings' sustainability performance. This suggests that interpretations and value judgements differ from one scorer to another, depending on their background and experience. Most SRTs adopt a deterministic scoring system, and do not acknowledge that there is a possibility for any variation. It is suggested here that variation in scores should be acknowledged in assessing the sustainability performance of buildings.

Implication (ii). No large difference in occupant satisfaction is observed between a sustainable building and a non-sustainable building. It might be reasoned that the occupants of the studied X and Y buildings may have 'acclimatised' to their environments, having used their respective buildings for more than a year. As a result, perhaps user performance criteria would only be useful if they were assessed shortly after occupants move into a building in order to truly distinguish the value between a sustainable building and a non-sustainable building. The suggested time frame of 6 months to 18 months to carry out an occupant satisfaction survey in LEED (USGBC, 2013) might need to be revised. Future studies involving larger sample sizes are needed to confirm this finding.

Implication (iii). Based on the analysis of 433 LEED projects, it is found that there is a lack of consistency in criteria scores for projects with similar sustainability awards. This implies that two buildings with similar awards may not necessarily have similar standards of performance. This might explain the contradictory findings on the benefits of investing in ‘green’ buildings (see Newsham et al., 2009; Miller et al., 2008 among others). Property investors should therefore take precaution and not just rely solely on the final sustainability awards of buildings in their investment making decision, because this could potentially be very misleading. Rather, each criterion score should be considered in detail.

6.6 Conclusion

All propositions (P6.1, P6.2, P6.3, P6.4) advanced in this chapter are rejected. Concerns are raised over the effectiveness of SRTs.

P6.1: There is no variation in criteria scores and weights (within each SRT), across different users. Based on the results of the survey (Figures 6.1, Appendix N and Q), it is clear that value judgements differ from one scorer to another in terms of sustainability performance. Criteria weights which have an impact on sustainability performance tend to differ depending on the perception of stakeholders. Because variation in both scores and criteria weights exist, this need to be acknowledged.

P6.2: There is no difference in scoring deterministically or in scoring that allows for variability within an SRT. From the results of the paired sample t-test (Appendix P), it is observed that a statistically significant difference exists between deterministic scores and scores which incorporate uncertainty. Hence, the use of deterministic scores in SRTs to assess sustainability performance is questionable.

P6.3: Occupants' satisfaction levels are expected to be higher in a sustainable building compared to a non-sustainable building. For this chapter, occupant satisfaction levels in case study buildings X and Y are compared. Interestingly, the results show no large difference in occupant satisfaction levels. Acoustic quality appears to be an issue in both buildings. One possible explanation, apart from SRTs not being able to truly distinguish a sustainable building from a non-sustainable building, is that respondents occupying buildings for more than a year may have become 'acclimatised' to their environment. Larger sample sizes are required to explore this further.

P6.4: Within an SRT, criteria scores are consistent for projects with similar sustainability awards. The results of the boxplot analysis (Appendix O, 433 LEED projects), do not support this proposition. It is observed that the range of scores for criteria within the same sustainability award is large.

CHAPTER 7 – THE STATE OF SUSTAINABILITY REPORTING AND ITS RELATIONSHIP WITH THE FINANCIAL PERFORMANCE OF PUBLICLY-LISTED CONSTRUCTION COMPANIES

7.1 Introduction

Adams and Narayanan (2007) claim that the reporting of sustainability matters has progressed beyond a superficial treatment in company annual reports. Stakeholders are increasingly seeking disclosures, not just on companies' financial matters but also on environmental and social practices (Ernst and Young, 2002; KPMG, 2005; Milne and Gray, 2007; Farneti and Guthrie, 2009). This is so even though the practice of sustainability is still in its developmental stages, with no total agreement on its definition (Bebbington, 2001; Adams and Narayanan, 2007), and alternative reporting terminology – corporate social responsibility (CSR), sustainable development (SD), triple bottom line (TBL), non-financial, and environmental, social and governance (ESG) – sometimes being used interchangeably (see Chapter 1).

Although benefits of sustainability reporting have been suggested (see Frost and Toh, 1998; Dickinson et al., 2005; Herbohn and Griffiths, 2007; Sciulli, 2009; UNEP, 1998), much is still unknown about the present state of such reporting with respect to specific industry sectors. Exploring the state of sustainability reports is crucial as they are the underlying basis by which ESG scores are derived. A poor state of reporting may possibly confirm the imprecision of such scoring and help explain the mixed results found in both Chapters 4 and 5. Also, there is a general lack of empirical evidence as to whether the disclosure or issuance of sustainability reports does lead to better financial performance. This needs to be investigated, as anecdotally the adoption rate of sustainability reports in particular industry sectors such as the construction industry appears to be slow (Carmichael and Balatbat, 2009).

To this end, the chapter focuses on the state of sustainability reporting of publicly-listed Australian construction companies using a checklist of 68 items in areas including climate change, environmental management, environmental efficiency, health and safety, human capital, conduct, stakeholder engagement, governance and other matters deemed to be of concern to institutional investors according to both the Financial Services Council (FSC) and the Australian Council of Superannuation Investors (ACSI) (FSC and ACSI, 2011). Following this, an investigation is conducted to determine if graph obfuscation is present in sustainability reports. It then presents the results of an empirical study on the impact of issuing sustainability reports on the financial performance of construction companies. Financial performance is measured via a range of financial ratios gathered through authorised access to databases of FinAnalysis and the Securities Industry Sector Research Centre of Asia-Pacific (SIRCA).

The chapter first outlines existing trends in the adoption of sustainability reporting together with relevant proposition development. It then presents the methodology used in this study and highlights key results on reporting and performance.

7.2 Background - trends in reporting

There are numerous reports and papers covering the adoption trends in sustainability reporting. Glass (2012) observes that the 'origins of environmental and social reporting can be traced back to Europe from the 1960s' (Glass, 2012, p. 89). Ioannou and Serafeim (2011, p. 8) claim that 'negative screening' by ethical investment funds had already set the scene for increased participation in this type of reporting since the 1980s. Kolk (2003) studied the extent of sustainability reporting of the Global 250 (G250 companies) between 1998 and 2001 and found that half of the multinationals showed continued and significant increase in such reporting. According to KPMG (2008), the percentage of companies publishing/releasing sustainability reports, categorised by country, increased steadily between 2005 and 2008: United States (41%), Spain (34%), Netherlands (31%), Sweden (39%), Italy (28%) and Canada (19%) (KPMG, 2008, p. 16). A more recent study by KPMG (2011) found that 95% of the G250 are now engaged in the reporting of corporate responsibility activities: 69% of the largest companies in 34 countries (N100) are found to conduct sustainability reporting, and participation from the consumer markets, pharmaceuticals and construction industries have more than doubled.

Within Australia, several attempts have been made to explore this further. Frost et al. (2005) claimed that the overall level of disclosures was generally low for 25 sample Australian companies when compared against the key indicators outlined in the GRI. Gibson and O'Donovan (2007) conducted a review of 752 environmental and social reports of 41 Australian companies from 1983 to 2003 and found that there appears to be a trend towards increased environmental disclosure in annual reports.

Construction industry

In Australia, the construction industry provides employment for many (in 2009/2010, approximately 938,000 people, representing about 9% of the total workforce - Safe Work Australia, 2009). The number of compensated fatalities in this industry between 2000/2001 and 2008/2009 ranged from 39 to 55 (Safe Work Australia, 2009). In 2009/2010 alone, the number of fatalities recorded was 41 in Australia, being the highest number of fatalities of all industries. On environmental matters, according to the Centre for International Economics (2007), 23% of Australia's total greenhouse gas emissions come from energy use in the building sector. The major contributors to emissions within construction are cement (20%), chemicals and petrochemicals (17%), iron and steel (16%) and aluminium/non-ferrous metals (5%). The Cooperative Research Centre (CRC) for Construction Innovation has also highlighted common barriers within the construction industry in Australia such as poor industry image, low levels of education in information and communication of technologies and management, poor employer – employee relations, procurement structures that promote adversarial site relationships and disparate occupational health and safety (OHS) legislation and guidelines across different states (CRC, 2004).

Because the construction industry has a large impact on the environment and community, it is worthwhile to observe the state of reporting in this industry. It might be anticipated that the construction industry would face close scrutiny from various stakeholders and therefore a higher commitment towards sustainability reporting could be expected from construction companies. This notion is further reinforced by the findings of Petrovic-Lazarevic (2008) where 17 selected Australian construction companies were said to be committed to sustainability reporting. This study aims to find some creditable evidence to validate if indeed the acclaimed commitment towards such reporting is true.

Studies examining the trends in sustainability reporting in the construction industry generally have sample sizes that are too small to draw any meaningful conclusions. For example, Lamprinidi and Ringland (2008) - 16 ‘global’ construction and real estate companies; KPMG (2008) - 3 to 8 companies; and Brown et al. (2009) - 12 companies. This chapter argues for a more thorough and meaningful analysis on the extent and quality of disclosures in the construction industry. The findings in this study include all publicly-listed construction companies in Australia. As well, the results discussed here are more recent and reflective of current sustainability reporting trends.

7.3 Graph obfuscation

Attention has turned to the use of graphs given the effect they have on user perception and the incentive for managers to use them as a tool to engage in impression management (Mather et al., 2005). Prior research has predominantly focussed on the use of graphs in financial reports (Merkl-Davies et al., 2011; Beattie and Jones, 2000; Beattie and Jones, 2002; Beattie and Jones, 1992). There are an extensive number of experiments concentrating on the effect of graph use on the decision-making of shareholders. The basis for such studies comes from the recognition that presentation format acts as a key information processing variable impacting the decision-making process (Beattie and Jones, 1992). Other studies have also shown that the impact of graphical format is dependent on the nature of the decision-making task (Blocher et al. 1986; Sullivan, 1988; Davis, 1989).

This chapter draws on the stream of literature relating to agency theory and impression management which has been the subject of much debate. Agency theory explores the issue associated with motivating an agent to act in the best interest of a principal (see Eisenhardt, 1989; Smith et al., 2005; Ekanayake, 2004). In the classical application of agency theory, the principal refers to shareholders while the agent refers to the company management. Eisenhardt (1989, p. 58) highlights two problems that can occur in agency relationships. ‘The first is the agency problem that arises when (a) the desires or goals of the principal and agent conflict and (b) it is difficult or expensive for the principal to verify what the agent is actually doing. The problem here is that the principal cannot verify that the agent has behaved appropriately’. This leads to information asymmetry where the company management has information that shareholders desire but do not have. The agent (company management) can choose to provide either more information to reduce information asymmetry or be opportunistic and act in its own interests instead of the principal’s (shareholders’) interests (Merkl-Davies and Brennan, 2011).

In the last decade, the adoption of sustainability reports by companies has grown tremendously (Cho et al., 2012). While there are views that sustainability reports help increased levels of accountability and meet the demand of stakeholders for transparency on both environmental and social issues, cynics have viewed them as nothing more than ‘greenwashing’ (Milne and Gray, 2007).

Studies focusing on the biased reporting of social and environmental performance as well as the role of sustainability reporting in mediating the relationship between management and stakeholders have been largely neglected. Only one study has attempted to examine (see Cho et al., 2012) evidence of obfuscation across corporate sustainability reports. Cho et al. (2012) analyse a sample of 120 sustainability reports and substantial evidence is found on enhancement and obfuscation in the graphs displayed. Merkl-Davies and Brennan (2007) maintain that manipulation can be visual and structural through the use of graphs. Beattie and Jones (2000) claim that the use of graphs to present information is powerful as it is easier to remember. Beattie and Jones (2002) conduct an experimental study to investigate the link between observed levels of graph distortion in annual reports and users’ perception of financial performance. They find that users with low levels of financial understanding are more likely to be misled by distorted graphs.

This chapter builds upon the study of Cho et al. (2012) by focusing on distortions in sustainability reports and using a similar definition of obfuscation (referring to materially distorted graphs) but conducted specifically within the context of the construction industry sector. Interestingly, despite the reliance on such reporting for decision making, there has not been any study of obfuscation through the use of graphs within the construction industry sector. This is particularly surprising considering that this sector is often labelled with the '3D' image (dirty, difficult and dangerous) and evidence of obfuscation is expected to be more prevalent. This industry sector is often associated with bad physical working conditions, long and unfavourable working hours, high accident rates, work-related illnesses and high emissions of greenhouse gases (Martinuzzi et al., 2011). Hence, it is anticipated that companies in this industry will have the motivation to engage in the obfuscation of such data so that society will perceive them in a favourable light.

7.4 Link with financial performance

Given the nature of the construction industry, it would be interesting to examine if companies that issue sustainability reports do yield better returns. Anecdotal evidence so far seems to suggest that construction practitioners have a tendency of viewing engagement in sustainability reporting as an extra financial burden (Carmichael and Balatbat, 2009). If some creditable evidence can be found that demonstrates a strong link between better ESG reporting and higher financial performance, then this would mean that the aforementioned perception that most practitioners have is false. Little research has rigorously examined the impact of ESG reporting on the financial performance of publicly-listed construction companies. This chapter accordingly fills a void.

7.5 Propositions

Based on the above background, the following propositions are explored in this chapter:

Proposition P7.1: Publicly-listed Australian construction companies are expected to achieve excellent levels of disclosure.

Proposition P7.2: The percentage of materially obfuscated graphs which depict construction companies in a favourable light is expected to be more than 50%.

Proposition P7.3: Construction companies that publish sustainability reports have better financial performance than those that do not.

7.6 Data and research methods

This section discusses the sample selection of companies and the sample composition. It also details the measures used to represent profitability ratios and equity valuation, as well as the methods used in the analysis.

7.6.1 Sample selection

The sample of 44 companies is selected from the Australian Stock Exchange (ASX) listings (ASX, 2012), based on a company's primary business focus being construction, and falling within the Global Industry Classification Standard's (GICS) of Capital Goods and Real Estate. The characteristics of the companies are summarised in Table 7.1. In Part III of the analysis, the sample is further divided into two groups, namely companies which released/published hard copy sustainability reports (R), and those which did not (NR).

Company	Average size from 2008-2010 (Log total assets, $)	Average leverage from 2008–2010(%)	Released R
1	8.63	197.2	No
2	9.13	162.4	Yes
3	8.60	281.5	Yes
4	7.27	109.8	No
5	8.92	3593.5	No
6	9.33	156.0	Yes
7	9.74	200.1	Yes
8	8.69	187.1	No
9	8.31	489.6	No
10	9.56	211.1	No
11	8.74	239.2	No
12	9.11	207.7	Yes
13	8.10	1118.2	No
14	8.28	225.4	Yes
15	9.52	266.2	Yes
16	8.82	240.7	No
17	8.03	191.1	No
18	9.59	302.1	No
19	7.59	153.3	No
20	9.93	198.2	No
21	8.90	190.5	No
22	8.91	181.0	No
23	9.40	-1556.9	No
24	9.88	368.5	Yes
25	9.97	319.3	Yes
26	8.79	208.3	No
27	9.88	155.3	Yes
28	8.60	333.6	No
29	8.53	237.5	No
30	8.92	155.2	No
31	8.48	3106.2	No
32	8.97	225.1	No
33	8.36	227.6	No
34	10.16	167.6	Yes
35	7.41	152.1	No
36	8.58	179.6	No
37	8.34	249.4	No
38	8.14	242.2	No
39	8.02	426.7	No
40	7.72	138.8	No
41	9.39	222.7	No
42	8.50	212.4	No
43	8.34	179.2	Yes
44	8.83	283.4	No

Table 7.1 Description of sample of construction companies (ASX, 2012).

7.6.2 Method

Part I

To obtain insights into the level of consistency in sustainability reporting, a cross-sectional study was conducted by examining a range of available documents such as sustainability reports, annual reports, media/press releases, corporate websites, codes of conduct and company policies. Based on the sustainability reporting guidelines published by the Financial Services Council (FSC) and the Australian Council of Super Investors (ACSI) (FSC and ACSI, 2011), 68 items within nine domains deemed to be most important to institutional investors, such as climate change, environmental management, environmental efficiency, other environmental matters, health and safety, human capital, conduct, stakeholder engagement and governance (FSC and ACSI, 2011), is cross-checked against the disclosures done by the construction companies (see Table 7.2 for items checklist). A score of 0 or 1 was adopted; 0 to mean absence while 1 to mean presence of information provided by the construction companies.

No.	**Climate Change**
1	Direct (scope 1) emissions by facility or process, including those occurring in equity stakes.
2	Indirect (scope 2) emissions associated with purchased electricity.
3	Supply-chain carbon emissions (scope 3).
4	Opportunities to pass carbon costs on to customers.
5	Opportunities to reduce carbon emissions and energy use.
6	Targets for reducing carbon emissions and improving energy efficiency.
7	Effective carbon liability management, including ways to reduce emissions or meet carbon liabilities at low cost.
8	An assessment of the physical risks from climate change.
9	Business opportunities that climate change regulation presents.
	Environmental Management Systems
1	Monetary values of fines and number of non-monetary sanctions for noncompliance with environmental laws and regulations.
2	Environmental provisions as reported on the balance sheet.
3	Number and severity of transgressions of environmental license conditions.
4	Losses of containment (number and severity).
5	Proportion of operations that are certified under the ISO 14001 Environmental Management Systems Standard.
6	Total count of process safety incidents.
7	Process safety total incident rate.
8	Process safety incident severity rate.
	Environmental Efficiency – Waste, water, energy
1	Type of waste produced by product and volume.
2	Targets for the reduction of waste.
3	% of waste re-used in the manufacturing process.
4	Water consumed (by quality/source) and targets for reduction.
5	% water recycled compared with base year.
6	Breakdown of energy used by source and comparison with base year.
7	Efforts to introduce energy efficient or renewable energy resources.
8	Energy saved due to conservation and initiatives to reduce energy consumption
	Environment – other issues
1	Hazardous waste emissions and reduction.
2	NO_x, SO_x and particulate emissions.
3	Emissions of ozone depleting substances by weight.
4	Total water discharge by quality and destination.
5	Details of toxic materials used in the manufacturing process.
6	Strategies for managing impacts on biodiversity.
7	Location and size of land use in or adjacent to areas of high biodiversity.
8	Description of significant impacts of activities, products and services on biodiversity in protected areas.
9	Habitats protected or restored.

Table 7.2 Summary of items checklist (for more details, see FSC and ASCI, 2011) (continued)

	Workplace health and safety
1	Training courses offered or held
2	Audits actually conducted by independent parties
3	Monitoring conducted/initiatives
4	Incidents analysed – breakdown
5	Number of near misses reported
6	% of hazards rectified
	Human Capital Management (HCM)
1	Board oversight of HCM.
2	Integration of HCM and people risks into risk management processes.
3	Executive remuneration linked to achievement of HCM objectives.
4	Employee diversity / anti-discrimination policies.
5	Processes to monitor and address discrimination.
6	Voluntary turnover rates
7	Employee engagement /satisfaction
8	External measurements / Assurance with standardised framework
9	Rate of return from maternity/parental leave.
10	Professional development training hours per employee.
11	% women at board and senior management levels.
12	Remuneration levels for male and female employees.
	Corporate Conduct
1	Corporate codes of conduct, the extent of their application and associated training.
2	Responsibility within the organisation for the code of conduct.
3	Linkages between remuneration policies and code of conduct.
4	Commitments to external initiatives, how they compare with industry standards and whether these are voluntary or obligatory.
5	Whistleblower policies.
	Stakeholder Engagement
1	Basis for identifying the key stakeholders with which to engage.
2	Frequency of key stakeholder engagement.
3	Engagement mechanisms (e.g. meetings, surveys, briefings, use of online media).
4	Main issues arising from stakeholder engagement.
5	Steps taken to respond to stakeholder feedback.
	Governance
1	Risk management policies and implementation.
2	The board's assessment of related party issues.
3	Director selection and board succession planning process.
4	Information on board evaluation practices and director independence.
5	The link between remuneration structures and company strategy.
6	The link between remuneration structures and shareholder returns.

Table 7.2 Summary of items checklist (for more details, see FSC and ASCI, 2011)

Euclidean distances, as used in distance mapping picture processing (Danielson, 1980; Kolounzakis and Kutulakos, 1992) and shortest path problems in operations research (Golden and Ball, 1978), are used to show the magnitude of differences in the level of disclosures. Essentially, the problem can be viewed as having two vectors (a vector representing what is expected of institutional investors and the other representing actual items disclosed) with nine elements representing the scores of each domain. Euclidean distances cover any shortfall associated with using any simple checklist summation, and account for levels of consistency achieved in reporting across all areas. The representative score (here, distance measured) is hence an accurate reflection of the level of consistency in reporting achieved throughout all domains. Because there are nine domains involved, Euclidean distance is measured by,

$$D(p,q)=\sqrt{(p_1-q_1)^2+(p_2-q_2)^2+....+(p_n-q_n)^2} \quad (7.1)$$

where D is the Euclidean distance, p is the maximum number of items in each respective domain, q is the number of disclosures by companies, and n = 9 represents the total number of domains. The scale used for measuring levels of reporting is as follows: Excellent (0 to 5), Good (5 to 15), Average (15 to 20) and Poor (> 20).

Part II

Mather et al. (2005) introduce the Relative Graph Discrepancy (RGD) Index and argue that it is more consistent and produces stronger results than the Graph Discrepancy Index (GDI) used in a majority of graph distortion studies (see Beattie and Jones, 2000, 2002, 1992 among others). According to Mather et al. (2005), RGD index is given as:

$$RGD=\left(\frac{g_2-g_3}{g_3}\right) \quad (7.2)$$

where g_2 is the height of the last column in the graph while g_3 is the actual height of the last column if plotted accurately (Cho et al., 2012); that is,

$$g_3=\frac{g_1}{d_1} \text{ x } d_2 \quad (7.3)$$

where d_1 is the value of first data point, d_2 is the value of last data point and g_1 is the height of the first column of the graph.

Changes in a given measure can be favourable or unfavourable depending on the items graphed. For example, a declining trend for lost time injury frequency rate (LTIFR) over a number of years is perceived as favourable while an increasing trend in number of hours spent on training workers is perceived as favourable. After Cho et al. (2012), selectivity is concerned with whether the choice of graphing an item coincides with a favourable trend, thus capturing impression management. This study uses a similar definition of selectivity.

Part III

A comparative analysis of financial performance was done based on the average values of groups R and NR. Financial performance indicators include profitability financial ratios and equity valuation (Barnes, 1987). A total of 10 financial performance indicators are used:

Profitability (5 measures):

- Return on assets (ROA)
- Return on equity (ROE)
- Return on invested capital (ROIC)
- Earnings before interest tax depreciation and amortisation (EBITDA) margin
- Net operating profit less adjusted taxes (NOPLAT).

Equity valuation (5 measures):

- Earnings per share (EPS)
- Dividend per share (DPS)
- Dividend yield (DY)
- Price to earnings ratio (PE)
- Enterprise value (EV).

Appendix J lists the formulae used for these indicators.

Two portfolios, R and NR, are created where portfolio return is computed using daily stock returns given by Equation (7.4),

$$\lambda = \log_e \left(\frac{price_t}{price_{t-1}} \right) \tag{7.4}$$

where t is the daily closing price of a stock. The annual stock return is obtained by adding the daily stock returns for all trading days in a particular year. Data for these calculations were obtained from the Securities Industry Research Centre of Asia Pacific (SIRCA).

The variance of each portfolio is also calculated. Portfolio variance is given as a function of the correlations, ρ_{ij}, of the individual stock, for all of the stock pairs (i,j) as shown in Equation (7.5), and may be taken as an indication of the return variability or return risk of a portfolio.

$$\text{Variance} = \begin{bmatrix} w_1\sigma_1 & \dots & w_n\sigma_n \end{bmatrix} \begin{bmatrix} 1 & \rho_{12} & \cdots & \rho_{1n} \\ \rho_{21} & 1 & \cdots & \rho_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \rho_{n1} & \cdots & \cdots & 1 \end{bmatrix} \begin{bmatrix} w_1\sigma_1 \\ \vdots \\ w_n\sigma_n \end{bmatrix} \tag{7.5}$$

7.7 Results

Part I - Level of reporting

Using Euclidean distances given by Equation (7.1), the level of reporting across publicly-listed Australian construction companies can be measured. The breakdown of the scale used to categorise the level of reporting is depicted in Table 7.3. The lower the score, the closer it is to the ideal situation; that is to say that the discrepancy between what is expected of institutional investors and actual disclosures is smaller. Based on the analysis, 66%, 25% and 9% of publicly-listed construction companies fall within the Poor, Average and Good categories respectively. No companies were found to have Excellent disclosure levels. The findings here may be consistent with the conclusion in Carmichael and Balatbat (2009) that a majority of contractors have yet to make a serious move to embrace sustainability practices and therefore are unable to sufficiently disclose information that addresses stakeholders' concerns. This could have also been attributed to either low sustainability awareness or construction practitioners simply not seeing a commercial benefit for doing so. The absence of mandatory reporting could also be a cause for such poor levels of reporting. UNEP (1998) speculates that reasons for not engaging in sustainability reporting are doubtful thoughts about the advantages it would bring to companies, competitors are not publishing such reports, clients including the general public may not be interested, the existence of other means of communicating environmental issues, it is difficult to obtain consistent data from operations and to select meaningful criteria and the possibility of it damaging the reputation of companies, especially those that have not been doing well.

Level of reporting	Range of scale	Percentage of companies
Excellent	0 to 5	0%
Good	5 to 15	9%
Average	15 to 20	25%
Poor	> 20	66%

Table 7.3 Level of reporting.

Conclusion on Proposition P7.1: A majority of publicly-listed construction companies have levels of reporting that are poor and fall short of the expectations of institutional investors.

Part II – Graph obfuscation

Table 7.4 gives a summary of items graphed by construction companies.

Items	**Number of graphs**
Social	**162**
Employee-related	91
Health and safety	44
Community involvement	10
Supplier-related	1
Customer-related	8
Others	8
Environmental	**122**
Emissions-related	42
Energy use/efficiency	15
Recycling/non-hazardous waste	13
Incidents/spills/remediation	1
Water-related	18
Product-related	19
Environmental savings	2
Other	12
Economic	**105**
Financial-related	105
Total	389

Table 7.4 Summary of items graphed.

From Table 7.4, it is observed that the most graphed items by construction companies fall under the social category (41.6%) followed by the environmental category (31.3%) and economic category (27%). Under the social category, the most graphed item is employee-related such as recruitment, retention rates and training hours offered to employees. Health and safety statistics comes next while the least graphed item is supplier-related. For the environmental category, the most graphed item is emissions-related and this includes scope 1 and 2 carbon emissions as well as other chemical compounds in the manufacturing of cement. It is interesting to compare these results to those of Cho et al. (2012). It is seen that the general pattern of graph usage across sustainability reports is similar. Cho et al. (2012) find that the most graphed items (total graphs in parentheses) under the social category is employee-related (256) while emissions is the most graphed item under the environmental category (231).

For the analysis, a RGD of 2.5% is selected as the materiality threshold following Mather et al. (2005) and Cho et al. (2012). Results show evidence of construction companies' bias towards graphing items with favourable trends (178 out of a total of 389 graphs). And out of the 178 graphs, 68% of them are distorted.

Conclusion on Proposition P7.2: Evidence of graph obfuscation is largely present in sustainability reporting of construction companies.

Part III - Comparative analysis

The results of the comparative analysis are summarised in Table 7.5. This is followed by relevant commentary.

Ratio	Year		
	2008	**2009**	**2010**
ROE (R)	15.1%	15.3%	5%
ROE (NR)	13.6%	5.6%	7.7%
ROA (R)	7.6%	8.2%	3.5%
ROA (NR)	7.5%	5.6%	5.4%
ROIC (R)	32.5%	40%	23.7%
ROIC (NR)	30%	24.4%	48.4%
EBITDA margin (R)	22.67%	21.4%	16.5%
EBITDA margin (NR)	16.1%	32.5%	7.8%
NOPLAT margin (R)	12.9%	13.2%	8.7%
NOPLAT margin (NR)	8.7%	9.3%	4.9%
EPS (R)	58.6	33.4	38.2
EPS (NR)	24.4	1.8	13.8
DPS (R)	40.5	30.7	29.4
DPS(NR)	16.8	10.3	11.1
DY (R)	5.1%	5%	4%
DY (NR)	6.3%	5.2%	3.7%
PE ratio (R)	13.4	9.8	18.6
PE ratio (NR)	-16.8	6.2	3.7
EV (R)	4.1 E+9	3.03 E+9	3.64 E+9
EV (NR)	1.0 E+9	6.85 E+8	8.08 E+8

Table 7.5 Summary of comparative analysis.

ROE. One of the most widely used measures for profitability is ROE, which gives the real return on shareholders' invested capital. ROE values are higher in both 2008 and

2009 for the group of companies that releases sustainability reports (R) compared to the group that does not (NR), except for 2010 where NR exceeded R by 2.7%.

ROA. ROA measures profitability and the effectiveness of companies in utilising their assets to generate profit. In contrast with ROE, ROA uses total assets as a denominator. ROA values are hence lower than ROE because total assets include liabilities and owner equity. Average ROA was found to be higher for R compared to NR in both 2008 and 2009, but not in 2010.

ROIC. ROIC reflects the effectiveness of a company in allocating its money and investing in its operations. R outperformed NR by 2.5% and 15.6% in 2008 and 2009 respectively, but underperformed in 2010, in a similar fashion to that for ROE and ROA.

EBITDA margin. The EBITDA margin provides an indication of cash flows in a company and is normally used by analysts to assess corporate performance. It is calculated from a company's earning power divided by its operating revenue. Average EBITDA margin is comparatively higher in 2008 and 2010 for R. The difference in EBITDA margin (between R and NR) in 2008 and 2010 is 6.57% and 8.7% respectively.

NOPLAT. For NOPLAT, profit is generated specifically from sales, while removing the effects of capital structure. NOPLAT provides an indication of how healthy a business is in generating profit without too much reliance on borrowing to fund its profit generating activities. It can be observed that R consistently outperformed NR in all three years (2008–2010).

EPS. EPS is perceived to be an important indicator in determining the share price of a company. Based on the analysis shown in Table 7.5, average EPS values for R are found to be much higher than NR by 34.2, 31.6 and 24.4 for 2008, 2009 and 2010 respectively.

DPS. As profit is generated by companies, they can either make the choice of retaining them in pursuit of future profitable opportunities or choose to distribute them to their shareholders. Effectively, DPS is the total sum of dividends paid annually for every ordinary share issued. Average DPS for R appears to be higher than NR, suggesting that there is a tendency for companies issuing sustainability reports to have higher dividend payouts, for the three years observed (2008–2010).

DY. DY is given as dividend per share over market price per share. By contrast to the other indicators, average DY values are marginally higher for NR than R in both 2008 and 2009, but not in 2010.

PE ratio. PE ratio is used to depict whether the share price of a company is overvalued as given by a higher PE ratio, or undervalued as given by a lower PE ratio. On average, the market price for R is consistently overvalued between 9 to 19 times more than average companies' earnings per share. The average PE ratio for NR appeared to be less consistent given the fact that they were undervalued by approximately 17 times in 2008, overvalued by approximately 6 times in 2009 and 4 times in 2010.

EV. EV represents the total value of a business debt free. This measure is used by analysts in evaluating the worth of a company typically in mergers and acquisitions. From the analysis, average EV was found to be much higher for R compared to NR between 2008 and 2010.

Stock return and variance. The stock return analysis is shown in Table 7.6. R outperforms NR in terms of expected stock return, and has a lower variance.

Grouping	Expected return	Variance
Construction companies (R)	-0.06	0.10
Construction companies (NR)	-0.36	0.77

Table 7.6 Stock return and variance.

Conclusion on Proposition P7.3: R outperforms NR in terms of stock return and largely has superior performance in terms of financial ratios. Accordingly, construction companies issuing sustainability reports largely outperform, in financial terms, those which do not.

7.8 Discussion

Several implications arise from this work. Through proposition P7.1, it is seen that the state of reporting for a majority of publicly-listed Australian construction companies is still poor. There appears to be a discrepancy in terms of construction companies, acclaimed commitment to sustainability reporting (Petrovic-Lazarevic, 2008) versus what is actually being reported. The results from this study could not find sufficient evidence to demonstrate that Australian construction companies are committed to sustainability reporting at least in the areas that are deemed to be of importance to institutional investors, such as climate change and human capital management, among others. Considering the increasing global trend in such reporting as discussed in the Background, these results may suggest that a majority of Australian construction practitioners are slow adopters of sustainability practices. The finding here is consistent with GRI's report on sustainability reporting in the construction and real estate industry sector (GRI, 2008).

And this could be attributed to various reasons such as not seeing a commercial benefit for it, lack of awareness or the non-existence of mandatory reporting. It could also be that construction companies' overemphasis on project demands such as budgets, schedules and quality issues have resulted in a negligence of long-term objectives and corporate sustainability issues receiving far less attention. Some of the suggested benefits of sustainability reporting are that: it allows the tracking of progress against specific targets; raises awareness about broad environmental and social matters throughout a company; and delivers corporate messages both internally and externally (Frost and Toh, 1998; Dickinson et al., 2005; Herbohn and Griffiths, 2007). The lack of engagement in sustainability reporting means that construction companies may stand to lose out on such benefits. As well, with the National Greenhouse and Energy Reporting

(NGER) Act 2007 in place, there is a possibility that construction companies that do not have an adequate system to account for greenhouse emissions and energy consumption may face future litigation issues.

According to the European Union on Sustainable Investment Forum (Eurosif, 2010), the Socially Responsible Investment (SRI) market has grown to €4986 billion as of December 31, 2009, up 338% between 2005 and 2009 (Dorfleitner and Utz, 2012). This has resulted in a rise in sustainability indices such as the Dow Jones Sustainability Index (DJSI) and FTSE4Good Australia among others. The basis of inclusion in these indices depends on how companies are rated in sustainability which is to a certain extent tied in to their level of reporting. Given the poor state of reporting, there is a possibility that the Australian construction industry may be rated less favourably and therefore lose out to other industry sectors that have already achieved a mature level of sustainability reporting. Perhaps the Australian Government may consider enforcing a mandatory reporting scheme to ensure a similar level playing field across all industries. Doing so not only promotes better comparability but may also help prevent other companies from 'greenwashing' or deliberately manipulating stakeholders' perceptions through discretionary reporting.

Evidence presented in this study suggests that construction companies may be biased towards the use of graphs to depict favourable criteria in sustainability reports. Proposition P7.2 in this study is hence accepted. This finding supports the perception put forth by critics that sustainability reports are used as a means for impression management rather than providing a meaningful account of their sustainability practices. Compared to financial reports, sustainability reporting is usually done on a voluntary basis and non-regulated which gives way to the potential for biased reporting.

This conclusion has an important policy implication. At the moment, there is no specific regulation concerning graph usage. Although advocate organisations such as the Global Reporting Initiative (GRI) has a working definition of what constitutes materiality, '... criteria that reflect on a company's significant economic, environmental, and social impacts or that would substantively influence the assessments and decisions of stakeholders' (GRI, 2011, p. 8), this is clearly subjective and insufficient. Hence, it would be helpful if GRI could prepare guidelines not just on what should be reported but also more explicitly mention how information should be presented with a particular emphasis on graph usage. This will definitely go a long way towards helping both parties, namely those involved in the preparation of sustainability reports and auditors, to judge whether graphs portray social and environmental information in a biased manner. These guidelines should not be developed based on 'gut-feel' which appears to be the case with a large majority of sustainability reporting tools (SRTs), but rather on the premise of scientific and empirical studies.

The results from proposition P7.3 (controlled for by country and industry sector) support the positive view that there are advantages for construction companies engaging in sustainability reporting. Further validation is required to strengthen this result given the shorter time frame of the analysis (between 2008 and 2010). Extending the time frame would have added more strength, but, considering that only less than a handful of publicly-listed Australian construction companies had engaged in sustainability reporting prior to 2008, the distinction between the two groups (R and NR) would not be well-established for these earlier years.

7.9 Conclusion

The chapter concludes the following on the three propositions examined.

Proposition P7.1: Publicly-listed construction companies might be expected to achieve 'Excellent' levels of disclosure in sustainability reporting. However, a majority of the construction companies in the studied sample (44 construction companies listed on the ASX) are found to have poor levels of reporting and failed to meet the level of demand for transparency set by institutional investors.

Proposition P7.2: The percentage of materially obfuscated graphs which depict construction companies in a favourable light is found to be more than 50%, suggesting that construction companies are guilty of abusing the use of graphs to appear favourable to the public.

Proposition P7.3: Construction companies that give sustainability reports are found to have better financial performance than those that do not. The comparative analysis on 44 construction companies listed on the ASX shows that the group of companies issuing sustainability reports (R) appear to outperform the group which does not (NR) in a number of selected financial ratios as well as stock return. Sample data with longer time series is required to further validate this finding.

CHAPTER 8 – AN ALTERNATIVE FRAMEWORK FOR SUSTAINABILITY REPORTING

8.1 Introduction

To facilitate sustainability reporting, several guidelines have been established, with the GRI framework (GRI, 2006) being one of the most prominent (see Chapter 2). The GRI framework provides a widely accepted guideline to report on the economic, environmental and social performance of companies. It is designed for use by a diverse range of companies in terms of size, sector and location. However, such guidelines have been criticised for being inward looking and for being able to be misused by companies to promote 'public relations' (Dickinson, 2005). This has prompted GRI to release several versions of its framework, the latest being G4, which includes the identification of environmental, economic and social aspects that are material to companies (GRI, 2013).

Other research in sustainability reporting include methodological reviews and critique (Guthrie and Abeysekera, 2006; Daub, 2005), use of GRI guidelines across Swedish companies (Hedberg and Malmborg, 2003) and the Australian public sector (Guthrie and Farneti, 2008). There are also studies exploring issues surrounding CSR communication; for example, Ashforth and Gibbs (1990) and Vallentin (2001) found that companies are more likely to attract stakeholder attention should they disclose their ethical and social ambitions. Morsing and Schultz (2006) propose three CSR communication strategies based on stakeholder theory (see also Donaldson and Preston, 1995; Freeman and Evan, 1990).

A majority of the current literature appears primarily focused on the content of sustainability reporting and companies' response to the demands of stakeholders with very few exploring ways to address deficiencies in such reports. Deficiencies in the current reporting approaches are outlined in Chapters 2 and 3 (also see Milne and Patten, 2002; Deegan et al., 2002; O'Donovan, 2002; Brown and Deegan, 1998; Hooks et al., 2002; Laufer, 2003; Bruno, 1997; Walker and Wan, 2011; Ramus and Montiel, 2005). This chapter contributes towards addressing these deficiencies by proposing an alternative sustainability reporting framework that provides a more objective way of characterising the sustainability performance of companies. This framework is also applicable for the sustainability reporting of buildings/infrastructure. Through the framework proposed in this chapter, the second research question (RQ2) in this thesis is addressed.

This chapter starts by providing a background on the evolution of corporate sustainability reporting. The reasons for engaging or for not engaging in such reporting together with existing deficiencies in current frameworks are then discussed. This is followed by a new framework proposal comprising of six distinctive elements.

8.2 Background

In the evolution of corporate sustainability reporting, the focus in the 1990s was predominantly on environmental reporting (SustainAbility and UNEP, 1998) with a growing interest in social concerns, particularly occupational health and safety (Marlin and Marlin, 2003). This was followed by the institutionalisation of the ‘triple bottom line’ (TBL) concept (Milne et al., 2008; Mitchell et al., 2012), reflecting the position that companies were starting to consider both environmental and social issues in addition to financial matters. Other terminology has also surfaced in the literature and public debate, including the non-financial indicators of corporate social responsibility (CSR), which attempts to encapsulate the broader responsibility of a company’s response to societal issues, environmental, social, governance (ESG) (Bassen and Kovacs, 2008), and Sustainable Development (SD) reporting (NZBCSD, 2002). In this chapter, these different types of reporting are broadly termed sustainability reporting.

Agreement on appropriate sustainability reporting is not settled, it being subject to ongoing debate among researchers and practitioners. The impact of existing reporting has been challenged; Buhr (2007) asks whether such a thing as sustainability reporting ever existed and claims that its case has yet to be made particularly with regard to any impact it might have on stakeholders. Nevertheless, there appears reasonable agreement that the act of providing an account of a company's activities has the potential to change behaviour, and it reinforces the feeling that companies need to be answerable to stakeholders.

KPMG report that the percentage of companies choosing to report on social and environmental issues increased between 2005 and 2008 (KPMG, 2008a), and the number of companies continued to increase up to 2011 (KPMG, 2011). Today, companies need to justify their activities to stakeholders, not just by disclosing financial information but also their social and environmental practices (Daub, 2005).

8.2.1 Reasons for reporting or for not reporting

Some of the reasons identified for corporate sustainability reporting include (SustainAbility and UNEP, 1998): the need to track progress against specific targets; to facilitate the implementation of an environmental strategy; to create awareness of broad environmental issues throughout a company; to convey a corporate message internally and externally; improved credibility through greater transparency and accountability in their business operations; reputational benefits; cost savings identification; increased efficiency; enhanced business development opportunities; and enhanced staff morale. KPMG (2008, 2011) provides a similar list with the later survey showing reputational and ethical considerations as the key business drivers of corporate sustainability reporting.

Farneti and Guthrie (2009) found that the primary reason for reporting was in order to satisfy stakeholders. Morhardt et al. (2002) suggest that the principal reasons are an attempt by companies to: meet regulatory requirements; reduce the possible cost of future regulations by being pro-active; mitigate the threat of non-compliance; improve stakeholder relationships; and reduce operating costs. In the GRI Sector Supplement for Public Agencies (GRI, 2006, p. 8), the reasons cited for sustainability reporting are: 'to promote transparency and accountability, reinforce organisational commitments and demonstrate progress, serve as a role model for the private sector, improve internal governance, highlight significance of its role as a consumer and employer in various economies, meet disclosure expectations and make information available to facilitate dialogue and effective engagement with stakeholders'. O'Dwyer (2002) suggests enhancing corporate legitimacy is the major reason. Larrinaga-Gonzalez et al. (2001) suggest that the motive for companies disclosing large amounts of environmental information is to influence the national environmental agenda and the public perception surrounding corporate environmental performance. Buhr (1997) discusses the rationale for sustainability reporting.

Reasons cited for not reporting are (SustainAbility and UNEP, 1998): doubt over the advantages it might bring to companies; competitors are not publishing such reports; clients, including the general public, may not be interested; the existence of other means of communicating environmental issues; there is difficulty in obtaining consistent data from operations and in selecting meaningful reporting criteria; and the possibility of damaging the reputation of companies, especially those that have not been doing well. It is interesting to note that some non-reporting companies in this survey have evolved to be leaders in sustainability reporting in recent years.

8.3 Deficiencies and limitations in current reporting practices

There are numerous deficiencies and limitations in current sustainability reporting practices. Some of these have been presented in Chapters 2 and 3, while others are carried over in this section. These deficiencies are addressed while outlining this chapter's proposed alternative framework.

As discussed in Chapter 2, some corporate sustainability reporting might be viewed as a tool to hide actual practices; Bruno (1997) mentions a large greenhouse gas emitter professing vigilant approaches to global warming, a leading ozone layer destroyer which takes credit for being a leader in ozone depletion, and a multinational company which cuts virgin rainforest, replaces it with monoculture plants and refers to the project as 'sustainable forest development'. According to Milne and Patten (2002, p. 375), the proclaimed sustainability initiatives of some companies merely act as 'a convincing facade to conceal the "back stage" activities' from a concerned public. A flow-on effect to this is the failure of ESG assessments relying on such reporting to truly distinguish the leaders from the laggards; numerous studies examining the link between ESG assessments of practices as reported and corporate financial performance have yielded mixed conclusions, possibly because of the inadequacy of current reporting (see Chapters 4, 5 and 7; Siew et al., 2011; Poelloe, 2010; Abramson and Chung, 2000; Derwall et al., 2004; Gompers et al., 2003; Opler and Sokobin, 1995; Orlitzky et al., 2003; Bauer et al., 2007; Hamilton et al., 1993; Angel and Rivoli, 1997).

Companies may manipulate stakeholders' perceptions via discretionary reporting. What appears to be happening is that some companies are selecting to report firstly only on their areas of strength, and secondly in a way friendly (and unique) to each company, in order to appear as good corporate citizens. This prevents a comparison of the sustainability achievements across companies because the information reported is different for each company. Langer (2004), for example, reveals that there are considerable differences between reports issued by different companies, and these differences go beyond differences in industry and company size.

The interpretation of such reporting becomes more challenging when many readers do not have specialist knowledge of a particular industry.

Companies also, quite naturally, report on any initiative. And they may make no distinction as to whether any of their activities are above and beyond business-as-usual; that is whether the activities were carried out with sustainability in mind or whether the activities were carried out for profit or legislated reasons, and they coincidentally fulfil some sustainability goal as well.

Companies also do not usually report their performance relative to other companies, or to any benchmark industry performance, and so stakeholders are left ill-informed.

It has also been raised that scoring systems developed in the literature to include social, economic and environmental TBL reporting have the problem that the choice of components and the assignment of weights is rarely justified and that the aggregation of different dimensions is often not meaningful (Becker, 1997).

8.4 Proposed alternative framework

The proposed alternative framework advanced in this chapter addresses the above deficiencies and limitations, along with others mentioned below. It comprises the following elements:

- Systems-based criteria selection.
- Quantitative measurement scales for criteria.
- Characterising each criterion by measures of central tendency and dispersion.
- The distinction of additionality.
- Criteria weighting.
- Combining criteria to give an overall score characterised by a measure of central tendency and a measure of dispersion.

8.4.1 Systems-based criteria selection

Sustainability performance is typically measured against a set of predefined criteria. Criteria play the role of summarising and condensing complex and diverse information about a company's practices into something manageable (Godfrey and Todd, 2001; Kessler, 1998; Meadows, 1998), and desirably measurable.

Criteria used in existing reporting practices suffer because:

- Criteria are not always independent of each other. That is, there is 'double counting' or redundancy of information being reported, and the overlap or correlation is not acknowledged or accounted for.
- Criteria are a mixture of information at different levels of detail. In different words, they are a mixture of criteria and subcriteria, and even sub-subcriteria. Accordingly it is not sensible to aggregate the information reported without acknowledging such hierarchies. Although reporting formats might purport to have core and lesser indicators, on closer inspection these are not systematic hierarchies.

As an example, Lozano and Huisingh (2011), under social issues, suggest criteria of employees' wages, work hours and benefit, employees' development, training and education and employees' rights. However, employees' rights may also involve training and education and also minimum wages or work hours, and therefore there is an overlap of the criteria as well as a mixture of levels of detail.

In order to eliminate the overlap between criteria and avoid the mixing of information at multiple levels, and get meaningful reporting, a systematic hierarchical approach for criteria selection is necessary. In systems terms, what is necessary to do is break a system down to subsystems to sub-subsystems etc., in a defined hierarchical fashion. This is referred to as a criteria breakdown structure (CBS) here. Adopting a systematic breakdown additionally eliminates the possibility of overlooking something, as might happen if the breakdown was done in an ad hoc way. The number of levels adopted in any particular CBS is up to the user or intent of the reporting, but typically might have, say, two to five levels. Decomposing to lower levels continues until the information can be appropriately characterised and measured.

Figure 8.1 demonstrates the thinking involved. The broad issue of sustainability reporting is broken down in terms of environmental, social and governance and economic issues (Level 1); ESG and TBL are marked on the figure to show their relationship to the CBS. Level 1 gets broken down to greater detail, and so on.

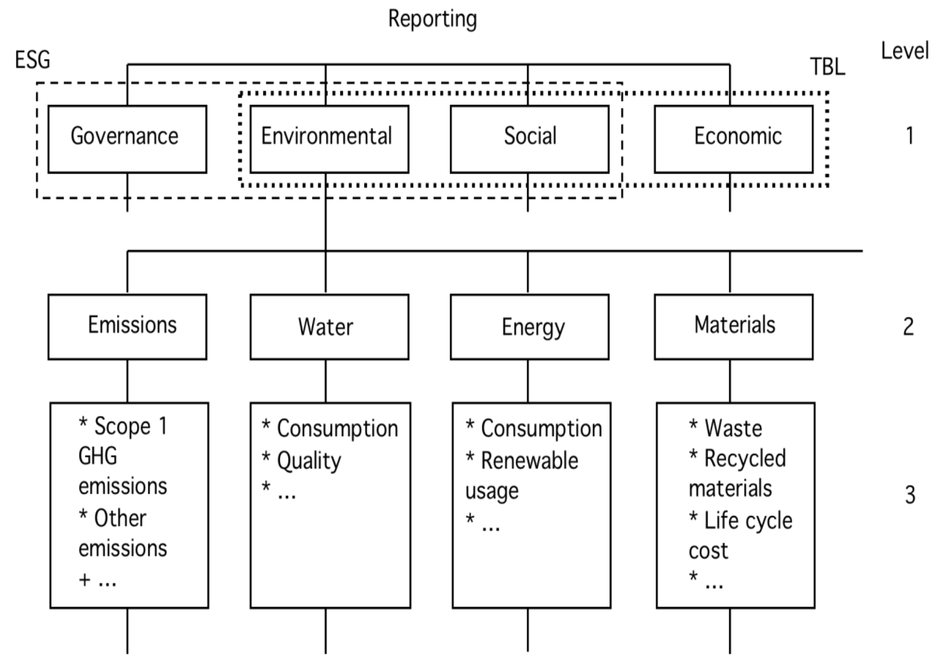


Figure 8.1 Example criteria breakdown structure (CBS) for sustainability reporting. Level 1 criteria, other than environmental, decomposed similarly.

It is remarked that a CBS is not unique, but can be chosen to suit the intent of the reporting. Different intents will lead to different decompositions, but as long as the decomposition is done systematically, then all information will be captured irrespective of any particular decomposition. Hueting and Reijnders (2004) comment on criteria selection. On proceeding down the hierarchy, generality gets replaced with detail.

It has been found in other endeavours, such as quality assurance, that by having highly structured criteria, better performance occurs in the criteria being evaluated, because it seems to concentrate people's minds.

In the following, the term 'criteria' is used to include subcriteria, sub-subcriteria etc, rather than spelling out these lower levels on every occasion. As the terms imply, subcriteria, sub-subcriteria etc. have the characteristics of criteria, but at lower levels and with lower-level denotation.

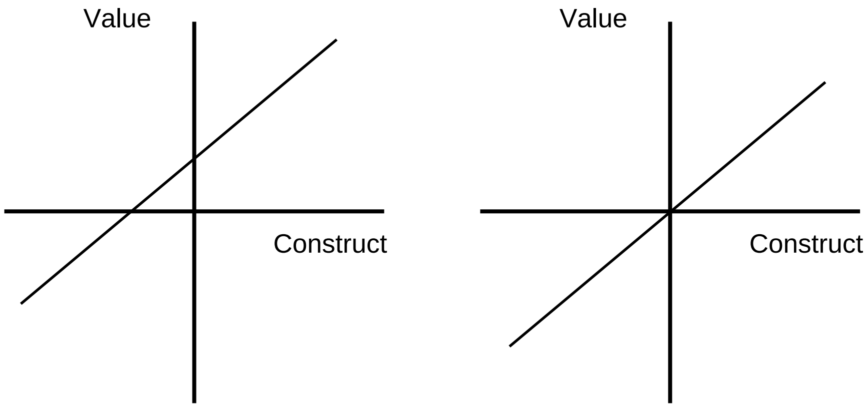
The CBS may be trimmed in two ways to make it more manageable, should it be considered too large:

- Where certain criteria are considered of lesser importance to others, the CBS diagram may be truncated. Thinking akin to the Pareto 80:20 rule might be used to isolate the more important criteria from the lesser important.

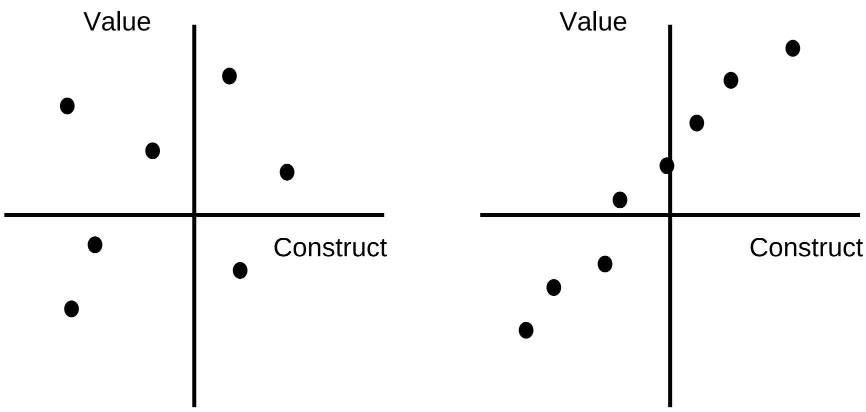
- Criteria may be converted to constraints. That is, rather than measuring a particular criterion, the particular issue is regarded as being acceptable provided it is greater than or less than some predefined standard of performance. The choice of this predefined constraint standard could be expected to involve subjective stakeholder judgement. For example, if 'Scope 1 greenhouse gas emissions' was a criterion, a company's total emissions would be reported; however this criterion could be reinterpreted as a constraint, such as 'Scope 1 emissions $\leq$ 50 Mt CO_2-e', whereby the company either satisfies this constraint or it doesn't. Where criteria cannot be put to a metric scale as outlined in section 8.4.2 below, a way of incorporating such qualitative criteria is to re-interpret them as constraints.

8.4.2 Quantitative measurement scales for criteria

Quantitative (***metric***) ***interval*** or ***ratio scales*** (Carmichael, 2013) are proposed, wherever possible, in this framework in order to minimise subjectivity and also to allow for an overall combined score, as detailed in section 8.4.6. For example, emissions might be measured in terms of carbon dioxide equivalent (CO_2-e), water in megalitres (ML), energy in petajoules (PJ), and materials in terms of percentage of use (%). However, it is recognised that even with defined measurement scales for each criterion, the interpretation of the reporting may introduce uncertainty; this is allowed for in section 8.4.3 below.



(a) Metric scales – interval and ratio



(b) Non-metric scales - nominal and ordinal

Figure 8.2 Example scales (after Lehmann, 1979).

The desire for quantitative measurement scales in all of man's endeavours is summarised well by Lord Kelvin (1883):

When you can measure what you are speaking about, and express it in numbers, you know something about it; when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts; advanced to the stage of science.

It is recognised that some criteria will be difficult to measure precisely, and some criteria will remain qualitative; for such criteria, the non-metric nominal or ordinal scales (Carmichael, 2013) will be more appropriate. There is the popular saying, 'Not everything that matters can be measured, and not everything that can be measured matters'; however, an attempt at uniformity across reporting needs to be attempted, and this will only be achieved through as much quantitative reporting as possible.

A ***nominal***, cardinal or categorical ***scale*** has no meaning in itself and does not relate to other scales. There is no relationship between the amount of the construct and the numerical measure. It denotes quantity but not order in a group. Multiple choice questions generally imply a nominal scale when numbers 1, 2, ... are attached to the different responses. The only number manipulation that can be performed relates to working out number of occurrences and frequencies. Statistical measures such as mean and standard deviation have no meaning. In an ***ordinal scale***, there is a relationship between the amount of the construct and the numerical measure but not the absolute value of the measure. It denotes order, quality or degree in a group such as first or second. Rankings, paired comparisons and semantic scales imply ordinal scales. An item ranked first is better than one ranked second but there is no indication as to how much better. An ordinal scale only permits medians and percentiles to be calculated. Where the differences between numerical measures, rather than the absolute values of the measures, is important, then this implies the use of an ***interval scale***. An interval scale permits means, standard deviations, parametric statistical tests, correlations, regression analysis, discriminant analysis and factor analysis, to be performed on the data. Only a few statistical tools cannot be used. A ***ratio scale*** implies meaningfulness to the absolute measurement values and the intervals between measurement values. As well, a value 0 implies the absence of the construct. All statistical analyses may be carried out on measurements on a ratio scale.

Existing sustainability initiatives are typically reported qualitatively rather than quantitatively, and existing frameworks tend to support such thinking. For example, Appendix D (Table D1) shows the nature of reporting against defined 'performance indicators' as used in GRI (2006). Qualitative reporting clouds an objective evaluation of a company's performance because different companies will have different standards of reporting, and the amount of disclosure may vary.

It is noted that some ESG scoring tools (for example, EIRIS and SAM) use Likert scales. As well, some reporting merely measures number of disclosures, as opposed to measuring any level of improvement or comparisons.

This chapter argues for the need, wherever possible, for quantitative measurement scales for each sustainability criterion for the above and following reasons:

- Quantitative data allow a combined analysis of objective and subjective criteria to derive an overall sustainability score, which permits improved company performance comparability and differentiation.
- Quantitative data can be reduced to qualitative interpretations if desired, but the reverse direction is not possible.
- The use of qualitative reporting, and including the use of nominal or ordinal scales, prevents any thorough statistical analysis, including the calculation of means and standard deviations, and the use of factor analysis for grouping data and regression for predictive modelling.

8.4.3 Characterising each criterion by measures of central tendency and dispersion

The scoring of sustainability criteria by researchers or independent agencies currently is carried out deterministically. That is, each criterion is scored with a single number or grade, and sometimes only a yes/no distinction. Uncertainty or variability in scoring is ignored. Yet underlying uncertainty is present for a number of reasons:

- The scoring is based on qualitative reporting, and often discretionary reporting.
- The English language is not precise, and lends itself to various connotations. While not being incorrect, phraseology chosen in reporting may lack precision, and this imprecision can be taken advantage of by report authors. This can contribute to what is popularly called ‘greenwashing’. As is well known in publishing, a good author is able to lead the mind of a reader to wherever the author desires.
- Reporting may be done by specialist reporting consultants not directly connected with or trained in a company’s activities, or attuned to specific industry jargon.

There may be a temptation to use standard formatting and general non industry-specific terms across multiple industries.

- The scorers may not be attuned to a company's particular activities, or may not have specialist knowledge of a particular industry, especially if the company is involved in technology.
- The scoring is subjective and reflects the context and background of the scorer.

The need to characterise the uncertainty in criteria can be demonstrated from the results of a simple experiment. The experiment is not intended to be rigorous but rather to example the point being made: Extracts of sustainability reports of two companies (A and B), specifically relating to environmental matters (of which two matters are reported here, namely effort in reducing energy consumption, and effort in reducing water consumption), and a glossary of terminology were distributed to a group of approximately 30 participants familiar with the stock market, selected for their availability and no other reason. Participants were asked to score the effort level of the two companies using a 10-point measurement scale, with 10 being the best and 1 the poorest. Figures 8.3 and 8.4 demonstrate typical scatter for such responses.

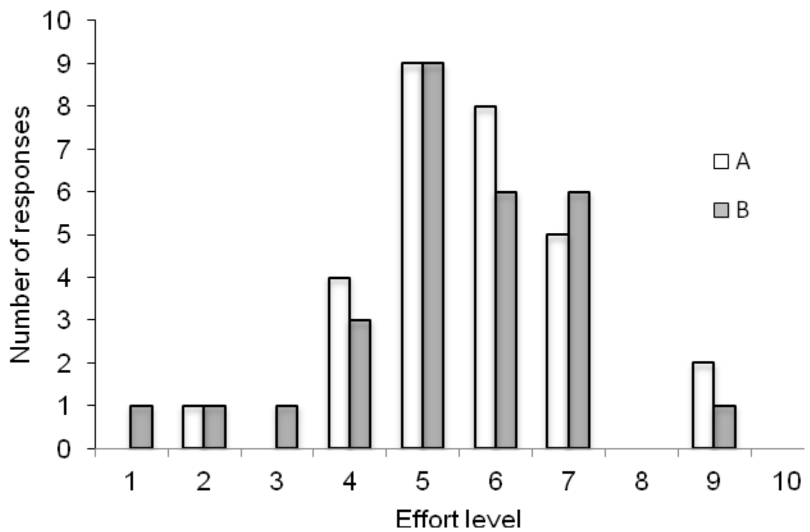


Figure 8.3 Experiment results - effort level in reducing energy consumption. Company A, mean = 5.7, variance = 2.2; Company B, mean = 5.4, variance = 2.8.

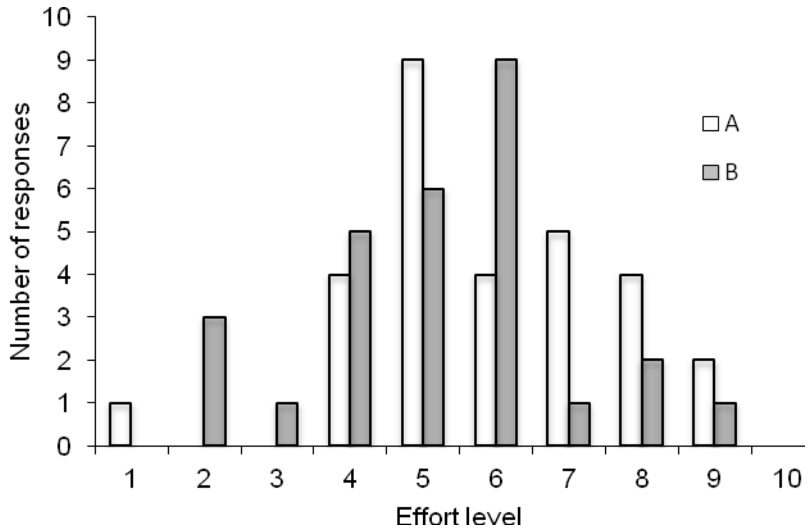


Figure 8.4 Experiment results - effort level in reducing water consumption. Company A, mean = 5.9, variance = 3.2; Company B, mean= 5.2, variance = 3.0.

Hence, to only use a single (deterministic) score, as is common with ESG scoring tools (for example, EIRIS, SAM, and KLD), will not reflect reality accurately. This chapter advances the view that two measures should be used to characterise each criterion, namely mean (expected value) and variance (standard deviation squared) in order to acknowledge the uncertainty and model it appropriately. Different criteria could be expected to have a range of variances from very large where a lot of subjectivity is involved, to very small where a criterion is tightly defined and technical.

This chapter suggests that a suitable way to obtain expected values and variances for each criterion, denoted X, is to ask scorers to first estimate optimistic (a), most likely (b) and pessimistic (c) values in line with PERT thinking leading to an expected value or mean, $E[X] = (a + 4b + c)/6$, and a variance, $Var[X] = [(c-a)/6]^2$ (Carmichael, 2006; Carmichael and Balatbat, 2008). Alternatively, estimates can be made of maximum, most likely and minimum values, and a triangular distribution assumed in order to calculate an expected value and variance based on this. Other methods exist and could also be used.

This chapter is suggesting that a company's sustainability score for each criterion be expressed as the pair $\{E[X], Var[X]\}$; that is, in terms of a measure of central tendency (mean or expected value) and a measure of dispersion (variance). Standard deviation could be used alternatively to variance.

Some criteria, of course, will exhibit no variability, in which case their variances are zero.

Example. Based on an interpretation of a company sustainability report, the hours per staff member allocated to training and education in the reporting year are interpreted or estimated by a scorer as follows: Optimistic = 35 h, most likely = 15 h, pessimistic = 5 h. Let X = Training and education. Then,

$$E[X] = (35 + 4 \times 15 + 5)/4 = 25 \text{ h}$$

$$Var[X] = [(35 - 5)/6]^2 = 25 \text{ h}^2 \text{ (or standard deviation = 5 h)}$$

8.4.4 The distinction of additionality

The scoring of each criterion within existing frameworks (GRI, 2006; Lozano and Huisingh, 2011) encompasses all activities associated with that criterion. This may not, however, be a true reflection of a company's attitude towards sustainability. Company activities can be broadly divided into:

i. Business-as-usual, implying the conventional profit motive and satisfying and necessary legislation, and
ii. Proactive, above-and-beyond type (i) sustainability practices.

The distinction is necessary because business-as-usual activities may have a coincident effect of contributing to sustainability, yet sustainability is not the prime reason for the activities. Two examples will illustrate this:

- Example 1. Consider a company that installs timing switches for its office lights. This saves energy and, as flow-ons, leads to cost savings and reduced carbon emissions. A prudent company would have undertaken such a timing switch initiative because of the cost savings irrespective of its view on sustainability. It is now disingenuous for that company to claim the light switches as a sustainability initiative, and to claim credit for reducing their carbon emissions.

- Example 2. There exists much legislation now on occupational health and safety and environmental protection. A company has to observe such legislation for fear of the company being fined and possibly also the company executives being fined and jailed. It is now disingenuous for a company to claim its safety and environmental activities, compulsorily required under the law, are sustainability activities.

Yet such disingenuous practices are what some companies are doing, and it contributes to the negative connotations associated with the term ‘greenwashing’. The company, in both examples, would be given a sustainability score based on doing no more than saving itself money or satisfying the law.

A true sustainability score should only reflect the proactive, above-and-beyond activities, or what is additional to business-as-usual. This is referred to as additionality here. In order not to confuse or mislead those stakeholders, who are not familiar with a company’s particular operations, only those activities, which are truly additional, should be included in a sustainability report and scored.

The notion of additionality is not new, but rather this chapter’s suggestion for its use in sustainability scoring is. Additionality is perhaps best known with reference to the Clean Development Mechanism (CDM) (UNFCCC, 2010; Balatbat et al. 2012) under the Kyoto Protocol. The mechanism allows developed countries to meet their carbon emission targets by investing in certified projects in developing countries. Carbon credits are only given to a project for reductions in emissions that are additional to any that would have ordinarily occurred in the absence of the project. The Carbon Farming Initiative (Carbon Market Institute, 2011) also uses additionality, where it requires emissions abatement and sequestration on a project to be additional to business-as-usual; that is, additional to that which would have occurred without the project. The definition of CSR by Vogel (2005) refers to corporate practices that enhance the workplace conditions and benefit society in ways that go above and beyond legal requirements.

This chapter suggests that sustainability reporting should only be on those activities that go beyond business-as-usual. All other activities will be reported separately, many appearing in usual business reports; some beyond business-as-usual activities may impact accounting reports negatively. This will require companies to distinguish the two types of activities (business-as-usual, and above-and beyond) and justify where the dividing line occurs between these two activities. However, this is not believed to be onerous because all that is being asked for is the point to which business-as-usual extends, before voluntary activities take over. A pro rata reporting and scoring would be possible where activities are a blend of business-as-usual and above-and-beyond.

8.4.5 Criteria weighting

The presence of multiple criteria introduces several issues:

- Criteria could be expected to have different levels of importance to each other. Some criteria may be more dominant than others. Commonly this is resolved by prescribing weights to each of the criteria and combining all the weighted criteria to give a single measure. Criteria which are considered more important are given higher weights. Selecting weights involves subjectivity and depends largely on the perceptions of stakeholders. Following the CBS, criteria are aggregated at lower levels to give a higher level measure, and so on up the CBS. There exists a number of ways in the multi-criteria decision making literature by which these weightings may be obtained; for example, using the Analytic Hierarchy Process (AHP) (Saaty, 1980) is one way.
- The weightings chosen by each stakeholder could be expected to be different. And so a consensus set of sensible weights, representative of all stakeholders, is required.
- The criteria will generally have different units of measurement; that is, they are non-commensurate. For example, emissions may be measured in terms of carbon dioxide equivalent (CO_2-e), water in megalitres (ML), energy in petajoules (PJ), and materials in terms of percentage of use (%). To combine the criteria into a single

measure, the criteria need to be converted to a common unit of measurement. The weightings chosen can be used to also accommodate this required change of units.

- When combining social and environmental criteria with economic criteria, the criteria may be conflicting. For example, implementing a social program may reduce company profit.

It is the relative values of the weights which are important, not their absolute values. Weights can be normalised to 1, 10, 100 or whatever is considered appropriate to stakeholders.

There is a need for establishing criteria weights which are representative of stakeholders. Where weightings are used in current scoring approaches, the weightings do not appear to be truly reflective of stakeholder interests, but rather appear to reflect special interests. There is a need to build up criteria weights systematically from lower to higher levels in the sense of Figure 8.1, and not combine them in an ad hoc way.

Establishing weights via methods such as AHP only has meaning if the criteria decomposition is systematic, and follows the suggestions given above.

8.4.6 Combining criteria to give an overall score characterised by a measure of central tendency and a measure of dispersion.

Section 8.4.3 above characterises each criterion by a measure of central tendency and a measure of dispersion. Criteria are now combined to give an overall sustainability score characterised similarly. The mean or expected value is adopted as the measure of central tendency, and variance (standard deviation squared) as the measure of dispersion.

The following addresses the CBS down to the subcriteria level, but the same thinking can be applied for lower levels.

Consider a criterion X_i, i = 1, 2, …, n, composed of subcriteria Y_{ik}, k = 1, 2, …, m, with mean $E[Y_{ik}]$ and variance $Var[Y_{ik}]$, obtained through first estimating optimistic, most likely and pessimistic values, as outlined above. Then,

$$X_i = v_{i1}Y_{i1} + v_{i2}Y_{i2} + ... + v_{im}Y_{im} \tag{8.1}$$

where v_{ik}, i = 0, 1, 2, ..., n; k = 1, 2, ..., m, are the subcriteria weightings obtained, for example, through AHP.

The expected value and variance of X_i become,

$$E[X_i] = \sum_{k=1}^{m} v_{ik}E[Y_{ik}] \tag{8.2}$$

$$Var[X_i] = \sum_{k=1}^{m} v_{ik}^2 Var[Y_{ik}] + 2\sum_{k=1}^{m-1}\sum_{l=k+1}^{m} v_{ik}v_{il}\,Cov[Y_{ik}, Y_{il}] \tag{8.3}$$

Equation (8.3) allows for possible correlation between the subcriteria, acknowledged through covariances $Cov[Y_{ik}, Y_{i\ell}]$. The variance expression can be written alternatively in terms of the subcriteria correlation coefficients, $\rho_{k\ell}$, between Y_{ik} and Y_{il}, $k,l = 1, 2, ..., m$,

$$Var[X_i] = \sum_{k=1}^{m} v_{ik}^2 Var[Y_{ik}] + 2\sum_{k=1}^{m-1}\sum_{l=k+1}^{m} v_{ik}v_{il}\,\rho_{kl}\sqrt{Var[Y_{ik}]}\sqrt{Var[Y_{il}]} \tag{8.4}$$

The total sustainability score, denoted SS here, is the weighted sum of the criteria X_i, i = 0, 1, 2, ..., n,

$$SS = \sum_{i=1}^{n} w_i X_i \tag{8.5}$$

where w_i, i = 0, 1, 2, ..., n are the criteria weightings obtained, for example, through AHP. The expected value and variance of SS become,

$$E[SS] = \sum_{i=0}^{n} w_i E[X_i] \tag{8.6}$$

$$Var[SS] = \sum_{i=0}^{n} w_i^2 Var[X_i]\frac{Var[X_i]}{(1+r)^{2i}} + 2\sum_{i=0}^{n-1}\sum_{j=i+1}^{n} w_i w_j Cov[X_i, X_j] \tag{8.7}$$

Equation (8.7) allows for possible correlation between the criteria, acknowledged through covariances $Cov[X_i, X_j]$. The variance expression can be alternatively written in terms of the criteria correlation coefficients between X_i and X_j, namely ρ_{ij},

$$Var[SS] = \sum_{i=0}^{n} w_i^2 Var[X_i] + 2\sum_{i=0}^{n-1}\sum_{j=i+1}^{n} w_i w_j \rho_{ij}\sqrt{Var[X_i]}\sqrt{Var[X_j]} \tag{8.8}$$

For independent criteria X_i,

$$Var[SS] = \sum_{i=0}^{n} w_i^2 Var[X_i] \tag{8.9}$$

For perfect correlation of the criteria X_i,

$$Var[SS] = \left(\sum_{i=0}^{n} w_i \sqrt{Var[X_i]}\right)^2 \tag{8.10}$$

Var[SS] is smaller for the assumption of independence compared with the assumption of correlation.

Where the variance terms are zero, the expressions reduce to a conventional deterministic treatment.

This chapter is suggesting that a company's sustainability score be expressed as the pair $\{E[SS], Var[SS]\}$; that is, in terms of a measure of central tendency and a measure of dispersion. Standard deviation could be used alternatively to variance.

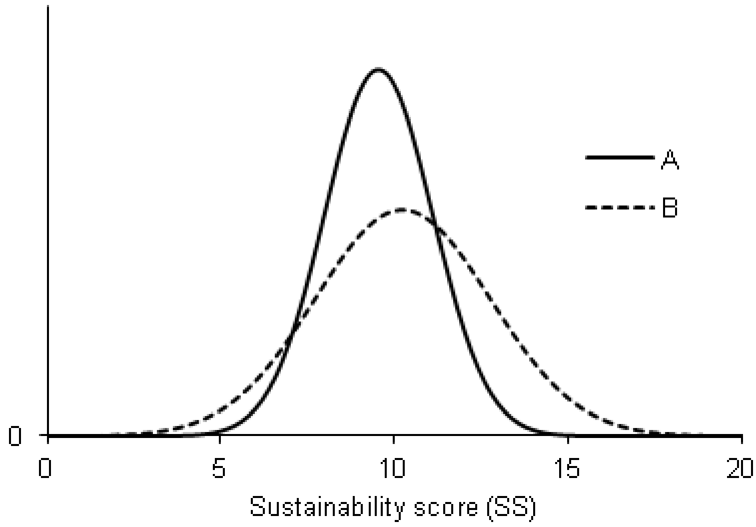
If required, SS can be represented by a probability distribution. A normal distribution appears reasonable because of its underlying additive components (criteria), but any distribution considered suitable can be used. The shape of a normal distribution is completely defined on knowing its expected value and variance, and associated probabilities are readily evaluated using standard normal probability tables. The Central Limit Theorem supports the assumption of a normal distribution when the number of additive criteria is large, irrespective of the shapes of the distributions of the underlying criteria (though it is noted that the proposed framework only requires expected values and variances for the underlying criteria, and makes no assumptions on their distributions).

Example: Consider a comparison of two companies A and B, over two criteria 1 and 2 considered independent, where the criteria weightings are $w_1 = 0.9$ and $w_2 = 0.75$. For criteria 1 and 2 respectively, let the expected values and variances, as calculated according to Section 8.4.3 above, be: X_1 $\{5.7,1.6\}$ and $\{5.9,2.0\}$; X_2 $\{6.3,4.7\}$ and $\{6.1,4.5\}$. Then,

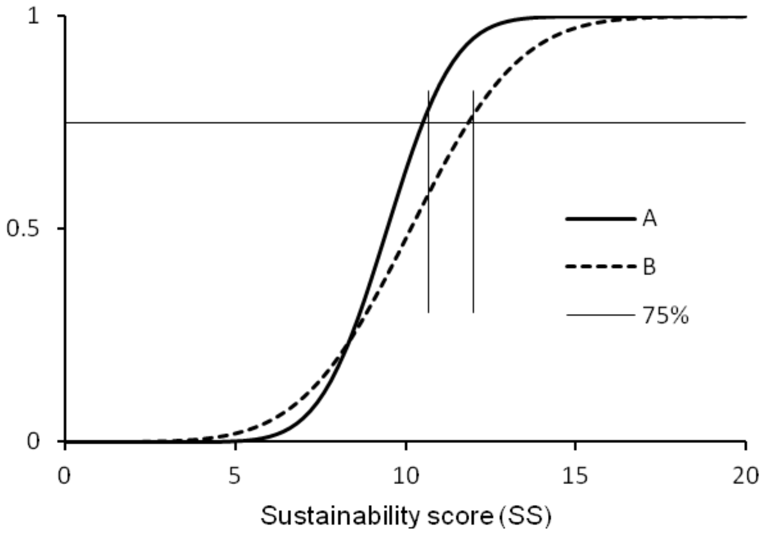
$$\begin{aligned}
&E[SS_A] = 0.9 \times 5.7 + 0.75 \times 5.9 = 9.6 \\
&Var[SS_A] = 0.9^2 \times 1.6 + 0.75^2 \times 2.0 = 2.4 \\
&E[SS_B] = 0.9 \times 6.3 + 0.75 \times 6.1 = 10.2 \\
&Var[SS_B] = 0.9^2 \times 4.7 + 0.75^2 \times 4.5 = 6.3
\end{aligned}$$

That is, the sustainability scores, SS, for companies A and B respectively are: $\{9.6,2.4\}$ and $\{10.2,6.3\}$. Using a normal distribution assumption for SS, the comparison of the two companies is shown in Figure 8.5a.

A suggested way of comparing companies against each other and against industry benchmarks is to compare attainments at different levels of probability. For this, the cumulative distribution function of Figure 8.5b can be used. As an example in Figure 8.5b, the 75% probability level is marked. Here the scores are 10.5 and 11.9 for companies A and B respectively.



(a) Comparison of probability density functions.



(b) Comparison of cumulative distribution functions.

Figure 8.5 Normal distribution plots of SS for companies A and B in the example.

8.5 Conclusion

The alternative framework advanced in this chapter addresses deficiencies and limitations of current approaches and practices. It comprises the following elements: (i) Systems-based criteria selection; (ii) Quantitative measurement scales for criteria; (iii) Characterising each criterion by measures of central tendency and dispersion; (iv) The distinction of additionality; (v) Criteria weighting; (vi) Combining criteria to give an overall score characterised by a measure of central tendency and a measure of dispersion.

The following items need to be agreed by a consensus of concerned stakeholders in order to implement the framework. This might best be done on an industry-by-industry basis.

- An appropriate criterion breakdown (CBS) structure.
- A measurement unit for each criterion.
- A weighting for each criterion.

Having these items in place, the framework then generates company scores automatically.

Consistent with KPMG's (2013) latest report on corporate sustainability reporting, this chapter argues that the current issue is no longer whether a company should 'report or not to report' but rather the focus should shift towards how to better capture quality reporting. On this note, the framework proposed here is rational and contains a number of benefits. It departs from existing deterministic reporting and provides for the inherent variability in sustainability criteria. The framework provides a more informed comparison of the sustainability practices of companies, and of improvements/deterioration in company performance over time, or against industry benchmarks or baselines. It provides a clear picture to stakeholders as to actual sustainability performance; this is compared with current practice where discretionary reporting makes it difficult to distinguish between true leaders and laggards and allows for 'greenwashing' to take place.

CHAPTER 9 – CLASSIFYING THE SUSTAINABILITY PERFORMANCE OF COMPANIES

9.1 Introduction

The current approach in SRI consists of a basic screening of companies according to a set of criteria to determine whether they should be included in a portfolio of investment (Dorfleitner and Utz, 2012). Given the rapid transformation of the SRI market, there have been calls for the development of more robust tools to help integrate sustainability into investment decision making (Fries et al., 2010). One of the major barriers to this integration process, however, is the inconsistency in terminology (Chapters 2 and 3), specifically on the subject of what constitutes sustainability performance. Anecdotal evidence shows that sustainability researchers or analysts have a tendency of arbitrarily defining sustainability performance without much rigour (Sharfman, 1996).

This chapter goes beyond the current approach and extends the framework in Chapter 8 by proposing a model to classify companies based on their sustainability (or ESG) performance. Firstly, hierarchical clustering as well as classification and regression tree (CART) techniques are used to develop three main clusters: 'Leader', 'Average' and 'Laggard'. This classification tree model is based on one of the most widely used corporate SRTs – the Kinder Lydenberg Domini (KLD) dataset. Secondly, because most SRTs tend to neglect the need to account for consistency in ESG performance and data trends (whether ESG performance is improving or declining over a certain period), a more generic regression tree model for classifying companies is further proposed.

Only after establishing appropriate methods and techniques to better define the ESG performance of companies can meaningful integration take place. Although the example given in this chapter is based on companies, the method proposed can be easily extended to classify the sustainability performance of building/infrastructure projects. The only difference is that input data from building SRTs (see Chapter 3) will be used instead of corporate SRTs.

The remainder of the chapter is organised as follows. A few different rating techniques and some essential concepts are first presented in the Background section. This is followed by a discussion of the data structure as well as the two trials conducted in order to develop the classification tree model. Then, a generic regression tree model which includes three proposed criteria, namely *ESG* – a measure of sustainability performance, *STD* - a measure of performance consistency, and *GRAD* - a measure of data trend is presented.

9.2 Background

There is a growing body of literature on ESG performance measurement, and includes investment policy (O'Rourke, 2003), screening approaches (Michelson et al., 2004) and engagement policies (Renneboog et al., 2008). Criteria covering transparency and credibility have been suggested (Michelson et al., 2004; Schrader, 2006; Koellner et al., 2005; Chatterji et al., 2007). Hallerbach et al. (2004) propose a framework for identifying investment opportunities based on a set of criteria which capture effects on society. Ballestero et al. (2012) recommend an approach for portfolio selection, combining both ethical and financial criteria. In their approach, three investor profiles are suggested, namely weak 'green' investor, strong 'green' investor and traditional investor depending on their unique utility functions. This chapter further extends the contributions made in this area by focusing particularly on classifying companies based on their ESG performance.

9.2.1 Rating techniques

Screening is one of several different techniques available to distinguish company performance. Two types of screening are employed in ethical portfolio selection (Knoll, 2002): negative and positive. Negative screening refers to a basic filtering out of companies based on the nature of their operations; for example, whether or not they are involved in perceived undesirable industries such as tobacco, gambling or manufacturing of weapons. Positive screening involves evaluating policies of companies for their ethical pursuits such as the proper management of water and emissions issues. Scores are given as part of the evaluation process and companies with higher scores are favoured (Ballestero et al., 2012).

Statistical techniques can also be used (Lee et al., 2006). These include the various forms of discriminant analysis (nearest neighbour discriminant, linear discriminant and kernel discriminant), regression analysis (logistic or linear regression), fuzzy sets, k-nearest neighbours and other forms of binary decision tree methods such as classification and regression tree (CART) as well as quick, and efficient statistical trees (QUEST) (Lemon et al., 2003). The development in operations research has also seen the rise in many advanced and reasonably complicated computational methods, for example, neural networks, genetic programming and support vector machines.

Robust methods that are appropriate for classifying the ESG performance of companies are linear discriminant analysis (LDA), regression analysis and binary decision trees. However, limitations do exist for some of these tools. LDA's performance decreases significantly when normality and equal variance assumptions are violated (Lam and Moy, 2002). Logistic regression has been criticised for its assumption about variation homogeneity (Lee et al., 2006). On the other hand, CART is seen to be advantageous because it can be easily applied to any data structure through the reasonable formulation of questions used as the basis for splitting. Also, the output structure is easy to interpret (Breiman et al., 1984) and more likely to select the independent criterion that is most different to the target criterion (Lemon et al., 2003).

9.2.2 Cluster analysis

Companies that share similar characteristics can be clustered together. Early studies defined groupings based on a narrow set of criteria (see Hunt, 1972; Porter, 1973), and while this allowed some degree of mapping of the structure of samples, it often failed to capture a multi-criteria construct (Hatten and Hatten, 1987). Cluster analysis, allowing for multiple criteria, provides a much richer description. Three main techniques exist to help with data clustering. They are hierarchical cluster analysis, k-means cluster and two-step cluster. Two-step cluster is used when very large data files (1000 cases is considered large for clustering) are available or when there are mixtures of categorical or continuous criteria. k-means can be used for moderately sized data sets, but the number of clusters must be known beforehand. Hierarchical clustering is recommended for small data sets, and for examining all possible solutions with increasing numbers of clusters.

Clustering enables more efficient decision making through diminished risk. In the management literature, this is known as organisational configurations, or companies that share a common profile with distinct criteria (Ketchen and Shook, 1996). A few studies have explored this. For example, Miller and Mintzberg (1983) identified companies by size, age and formality. Miles and Snow (1978) introduced organisational typologies. Galbraith and Schendel (1983) recommended the use of taxonomies in organisational configurations.

9.2.3 ESG scoring tools

There are a number of ESG scoring tools available to measure the ESG performance of companies. These include KLD, EIRIS, SAM, FTSE4Good, MSCI's ESG index, Asian Sustainability Rating (ASR), RepuTex, and Asset4 ESG scores. All of these tools are deterministic, and only some disclose information about the criteria and methodology used behind their ESG measurements. A discussion of these tools and their areas of focus are summarised in Chapter 2.

9.3 Tree model

This section explores the classification of 73 NYSE companies (rated by KLD between 1997 and 2011). The data structure is first discussed. Subsequent analyses are divided into two trials:

1. Trial 1, using non-standardised company data; that is, ENV, SOC and GOV criteria in their original form.

2. Trial 2, using standardised company data; that is, ENV, SOC and GOV criteria where, for each criterion, the mean is set to 0 and the standard deviation is set to 1.

Each trial consists of two parts:

i. The first part explains the results from the hierarchical clustering process where the aim is to group the 73 companies into different clusters.
ii. Having identified the cluster that each company belongs to (from the first part), a tree model is developed using the classification tree technique. The process and properties of the tree model are explained.

9.3.1 Data structure

Before clustering is carried out, there is a need to gauge whether the criteria considered (ENV, SOC, GOV) are likely to lead to a distinctive taxonomy. A sensible way to start is by plotting against different criteria pairs to obtain insights of the data structure. Figure 9.1 depicts a multi-criteria plot where the first, second and third rows represent ENV, SOC and GOV criteria. Vertical axes for the rows (from top to bottom) represent ENV, SOC and GOV values respectively. The first, second and third columns are also ordered in a similar fashion - ENV, SOC, GOV criteria from left to right. Horizontal axes for the columns (from left to right) represent ENV, SOC and GOV values respectively. Note that the range of values (in parentheses) for each criterion is different - ENV (between -1.61 to 2.3), SOC (between -2 to 6.57) and GOV (between -2.12 to 0.96). The measurement scales on both vertical and horizontal axes (see Figure 9.1) reflects this. Diagonal plots (North-West to South-East) are empty because they are merely plots of criteria against themselves. From Figure 9.1, there appears to be reasonable data separation, which makes ENV, SOC, and GOV ideal criteria for developing a taxonomy. The mean and standard deviation of the criteria in parentheses $\{\mu, \sigma\}$ are given as: ENV {0.6, 0.54}; SOC {1.62, 1.77}; GOV {-0.47, 0.48}.

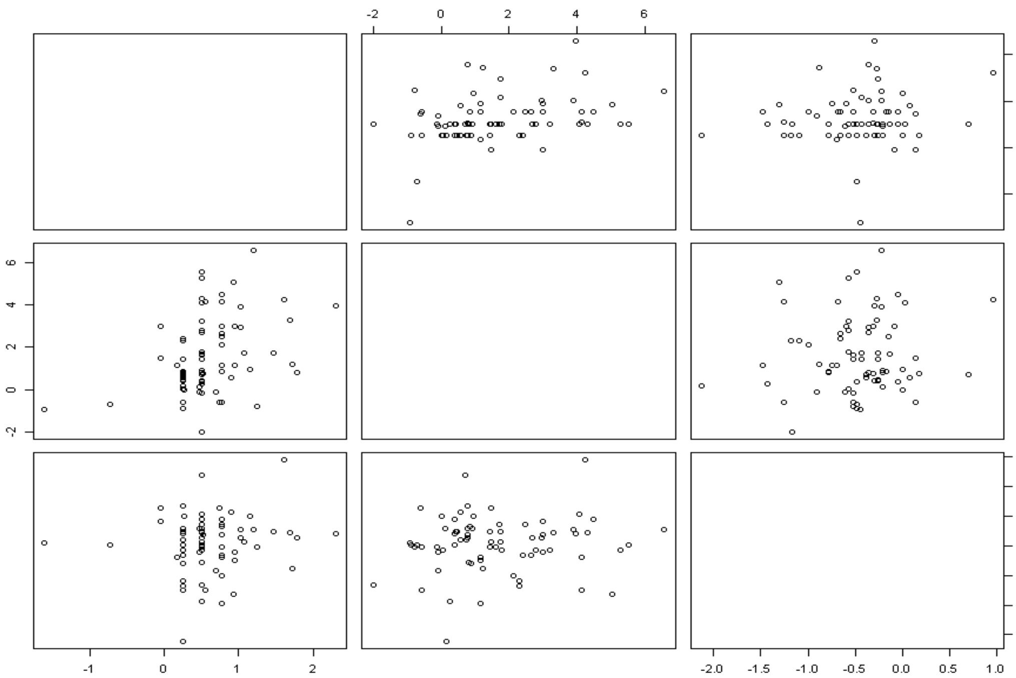


Figure 9.1 Plotting against different pairs of criteria (ENV, SOC, and GOV).

9.3.2 Trial 1

Part (i) - Hierarchical clustering

Hierarchical cluster analysis is preferred here over k-means or two-step cluster approaches because of the relatively smaller data set and the non-existence of categorical data. The construction of different clusters is done using the 'Stat4' package in the R program (R Development Core Team, 2009; Crawley, 2007).

There are two subdivisions of hierarchical cluster analysis: agglomerative hierarchical clustering which begins with the assumption that every company is an individual cluster and is joined successively to other companies; and divisive clustering where every company begins in one large cluster and ends in individual clusters. The function *hclust ()* from package 'Stat4' is the primary function for agglomerative hierarchical clustering while the function *diana ()* is used for divisive hierarchical clustering (R Development Core Team, 2009). The information required to carry out a cluster analysis includes:

- The distance between companies.
- Determining which clusters are merged at successive steps.
- The number of clusters required to represent data. In cluster analysis terminology this is known as 'cluster solutions' (Ketchen and Shook, 1996).

A large distance means that the characteristics of companies are distinctive. The distance between two companies is calculated using the Euclidean distance form given by:

$$D(x,y)=\sqrt{(x_1-y_1)^2+(x_2-y_2)^2+....+(x_n-y_n)^2} \tag{9.4}$$

where D is the Euclidean distance, x is a given criterion (ENV, SOC or GOV) belonging to one company, y is the equivalent criterion (ENV, SOC or GOV) belonging to another company, and n represents the total number of criteria. In cluster analysis, the sum of squared Euclidean distances can also be used (Akkucuk, 2011).

Agglomerative hierarchical clustering is first carried out on the 73-company data using the *hclust ()* function. In agglomerative hierarchical clustering, each company is first assumed to belong to an individual cluster. With a sample of 73 companies, this means that there are 73 clusters. The *hclust ()* function defines the distance between two clusters as the maximum distance between a pair of companies, one in each of the clusters. Mathematically, this can be represented as (Noor Rashidah et al., 2011),

$$D'(A,B) = \max\{d(a,b)\} \tag{9.5}$$

where D'(A, B) represents the distance between two clusters; d(a, b) is the distance between companies a $\in$ A and b $\in$ B; and A and B denote two different clusters.

At every stage of the clustering process, the two nearest clusters are merged into a new cluster. This process is repeated until the whole data set is agglomerated into one single cluster; that is, all 73 companies are combined as one. The output of agglomerative hierarchical clustering is a dendrogram which, for this data set, is shown in Figure 9.2.

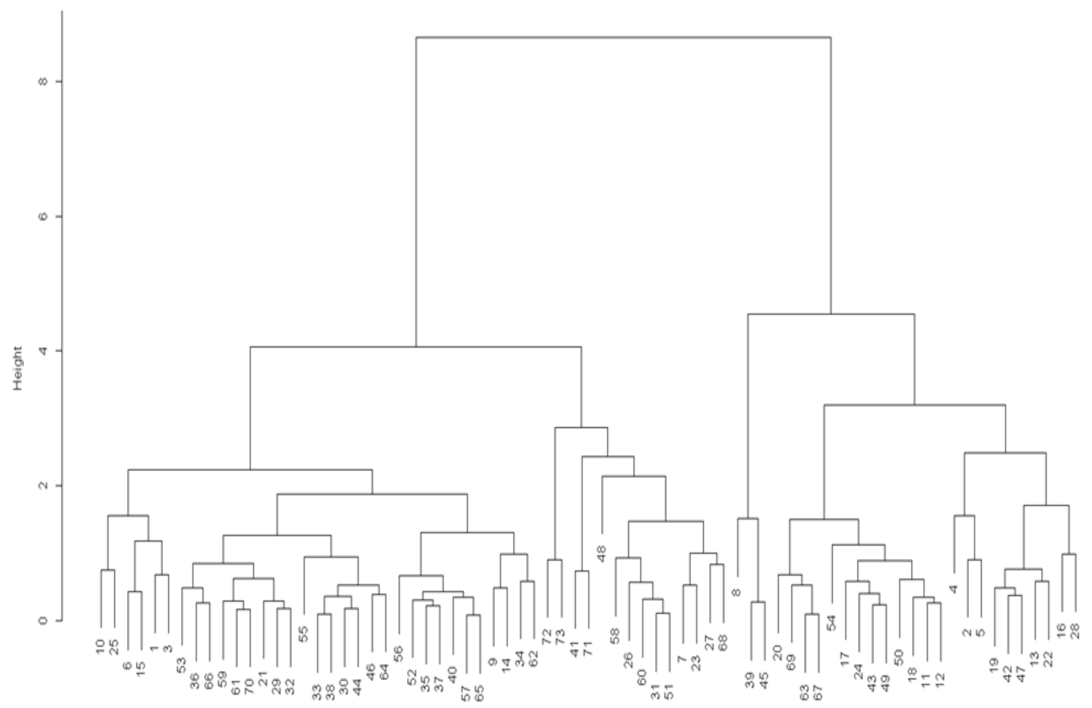


Figure 9.2 Dendrogram for case data set (Trial 1).

A dendrogram provides a visual representation of the distance at which clusters are combined. The horizontal lines represent joined clusters. In the dendrogram of Figure 9.2, distance (see Equation 9.4) is labelled as 'Height'. The distance between clusters is useful in deciding the number of cluster solutions that would be suitable for the data set. Larger distance (at which clusters are joined) implies that the characteristics between clusters are more distinctive.

From Figure 9.2, there are clearly two very distinctive clusters, one on the left and the other on the right (joined at height 8.3). Each of these two clusters can be broken down further to two more distinctive clusters (at approximately height 4). Currently, there is no generally accepted procedure for deciding the number of cluster solutions, much of the decision lies with the value judgement of the researcher. To help guide this decision making, statistics such as the median values of company data (ENV, SOC and GOV criteria) may be examined for a different number of cluster solutions. The median value is useful because it gives the mid-point of the company data (ENV, SOC and GOV criteria) in each of the clusters.

The *cutree ()* function (Crawley, 2007) is used to 'cut' the dendrogram into two possible cluster solutions, namely:

- A 3-cluster solution. These clusters are labelled as X, Y, Z in Table 9.1a, and
- A 4-cluster solution. These clusters are labelled as I, II, III and IV in Table 9.1b.

A different number of cluster solutions (for example, more than 4-clusters) could be suggested; however, in the context of this analysis, users may find having too many clusters less useful as a way of distinguishing companies' sustainability performance. The median values of company data (ENV, SOC, GOV criteria) for both the 3-cluster and 4-cluster solutions are then compared. From Tables 9.1a and 9.1b, selecting a 4-cluster solution seems to be advantageous because it recognises the existence of a cluster labelled III, which has comparatively lower ENV, SOC and GOV values.

Cluster	ENV	SOC	GOV
X	0.511	0.711	-0.433
Y	0.767	3.00	-0.356
Z	0.511	5.52	-0.478

Table 9.1a Median values of company data (ESG, SOC, GOV criteria) for a 3-cluster solution (Trial 1).

Cluster	ENV	SOC	GOV
I	0.511	0.856	-0.300
II	0.767	3.00	-0.356
III	0.489	-0.573	-0.545
IV	0.511	5.52	-0.478

Table 9.1b Median values of company data (ESG, SOC, GOV criteria) for a 4-cluster solution (Trial 1).

Part (ii) - Classification tree

Based on the part (i) results, a 4-cluster solution has been selected for the 73 companies. However, it might be perceived as too 'labour intensive' if, every time data for a new company becomes available, the clustering process is repeated to identify which cluster that company belongs to. It would be useful if a tree model could be developed in conjunction with these clusters. With a tree model, companies can be readily segregated into each of the identified clusters more efficiently.

A classification and regression tree (CART) analysis is useful for developing a tree model. Based on CART terminology, if the response criterion is categorical, then it is called a classification tree, while if the response criterion is continuous, it is called a regression tree.

Data from part (i) are used for the construction of a classification tree. Each of the 73 companies is labelled I, II, III, or IV based on a 4-cluster solution (Trial 1). The labels represent the unique cluster that a company belongs to and are treated as response criterion (categorical) in a CART analysis. ENV, SOC and GOV criteria are treated as predictor criteria. The construction of classification trees is done using the 'tree' package in R (Crawley, 2007).

In deriving a classification tree, binary recursive partitioning (see Crawley, 2007) is applied where the 73 companies are successively split along the coordinate axes of the predictor criteria (ENV, SOC and GOV) so that, at any node, the split which maximally distinguishes the response criteria (clusters I, II, III or IV) in the left and right branches is selected (Crawley, 2007). Splitting continues until nodes are 'pure' (that is, all companies within that node have the same properties) or if there is insufficient number of companies to warrant a further split (Maindonald and Braun, 2003).

Each possible split based on each of the predictor criteria (ENV, SOC and GOV) is assessed in turn and the split giving the greatest decrease in 'impurity' is selected (see Breiman et al., 1984, Maindonald and Braun, 2003). 'Impurity' in nodes is defined as deviance and is given in Equation (9.6) (Breiman et al., 1984):

$$\text{deviance} = -2\sum_{k} n_{ik} \log(p_{ik}) \tag{9.6}$$

where k denotes the clusters (I,II,III or IV), i denotes the node and n is the number of companies. For any given node i, the proportion of companies in each of the clusters (I, II, III or IV) is called node proportions given by p_{ik} (Archer, 2010, p. 2).

Once the splitting process is completed in R, a classification tree model is obtained as shown in Figure 9.3 (see Appendix R for codes). For all of the tree models in this chapter, the splitting criteria are displayed on the horizontal lines. The tree is interpreted as follows: if a splitting criterion is satisfied, then proceed along the left path, otherwise proceed along the right path. The terminal nodes represent the cluster labels (namely, I, II, III or IV). As can be observed, the SOC criterion appears to be the only criterion used in developing the tree model. This suggests that SOC is a dominant criterion and therefore some standardisation of the criteria scales is possibly required.

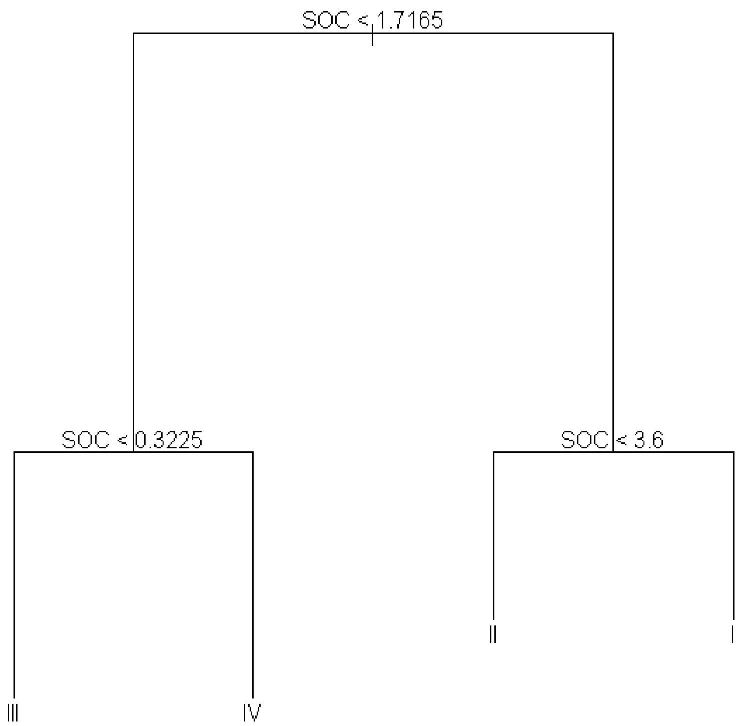


Figure 9.3 Classification tree model (Trial 1).

9.3.3 Trial 2

Part (i) - Hierarchical clustering

A second trial run is conducted but this time with standardised data. The dendrogram produced based on agglomerative hierarchical clustering is shown in Figure 9.4. There are two obvious clusters, one to the left of the diagram and the other to the right, although the left cluster now appears to have more companies compared to the analysis with non-standardised data (compare Figures 9.2 and 9.4).

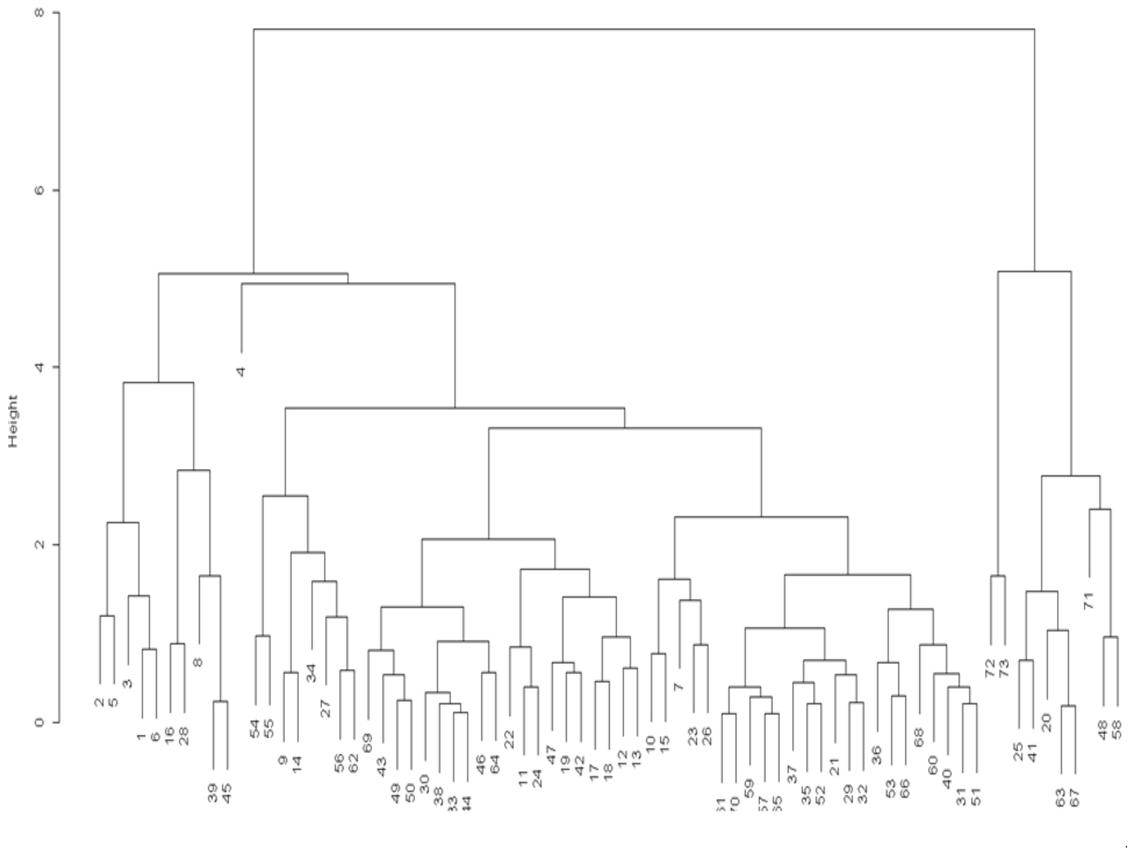


Figure 9.4 Dendrogram (Trial 2).

In a similar fashion to part (i) of Trial 1, the median values of company data (ENV, SOC, GOV criteria) are compared for a few different cluster solutions (2 to 4). A 4-cluster solution is selected because of the existence of cluster III with negative median values for the GOV criterion (see Table 9.2), possibly implying the existence of a distinctive cluster. This is not present in, say, a 2-cluster solution. On the other hand, a 3-cluster solution is deemed to be inappropriate at this stage due to the existence of all negative median values for ENV, SOC and GOV criteria.

Cluster	ENV	SOC	GOV
I	1.366	1.373	0.105
II	-0.169	-0.376	0.233
III	-0.407	-0.521	-1.577
IV	-3.310	-1.373	0.013

Table 9.2 Median values of company data (ESG, SOC, GOV criteria) for a 4-cluster solution (Trial 2).

Part (ii) – Classification tree

As before, companies are labelled I, II, III or IV depending on which cluster they belong to. These labels are treated as response criteria (categorical) while ENV, SOC and GOV criteria are treated as predictor criteria for input into the CART analysis in R as is done in part (ii) of Trial 1. This yields the classification tree model shown in Figure 9.5. As anticipated, SOC is no longer the dominating criterion. Cluster IV (Trial 2) is not identified in this particular model because it turns out that it only has 2 member companies out of the 73 and is therefore negligible.

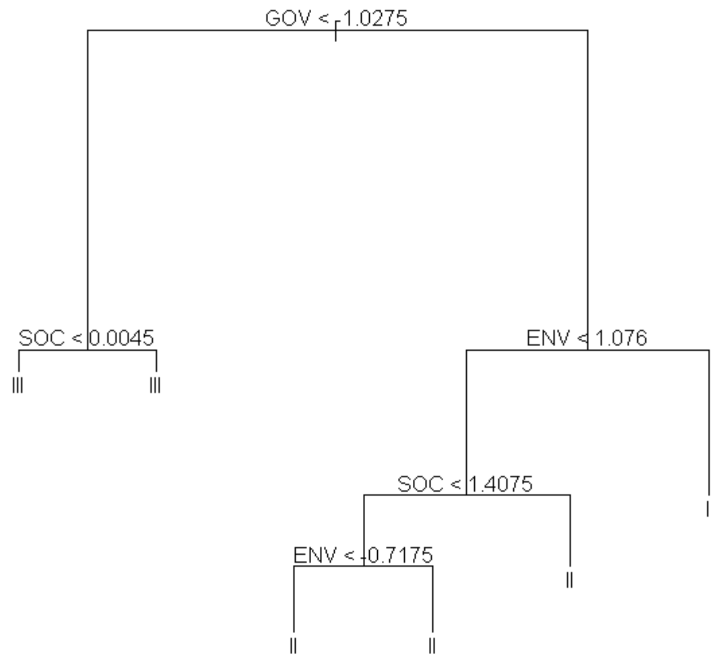


Figure 9.5 Classification tree model (Trial 2).

Figure 9.6 gives the R output code, which explains the properties of the classification tree model using standardised company data (ENV, SOC, and GOV criteria). The order and format of the code is: node), split, n, deviance, yval, and (yprob). The terminal nodes, totalling six, are denoted by asterisk. The node number is on the far left. Next is the split criterion which depicts the value of each criterion (ENV, SOC or GOV) that is used to create the split. The number of companies (n) going into the split comes next. Deviance is given by Equation (9.6). yval represents the most dominant cluster (either I, II, III or IV). The most dominant cluster is defined as the cluster with the highest proportion of companies in a given node. yprob is the node proportion (described in Trial 1, Part (ii) - Classification tree) from left to right - Clusters I, II, III, IV respectively (Crawley, 2007).

```
node), split, n, deviance, yval, (yprob)
      * denotes terminal node

 1) root 73 123.500 II ( 0.13699 0.72603 0.10959 0.02740 )
   2) GOV < -1.0275 10  10.010 III ( 0.20000 0.00000 0.80000 0.00000 )
     4) SOC < 0.0045 5   0.000 III ( 0.00000 0.00000 1.00000 0.00000 ) *
     5) SOC > 0.0045 5   6.730 III ( 0.40000 0.00000 0.60000 0.00000 ) *
   3) GOV > -1.0275 63  65.140 II ( 0.12698 0.84127 0.00000 0.03175 )
     6) ENV < 1.076 55  34.220 II ( 0.03636 0.92727 0.00000 0.03636 )
      12) SOC < 1.4075 50  16.790 II ( 0.00000 0.96000 0.00000 0.04000 )
        24) ENV < -0.7175 5   6.730 II ( 0.00000 0.60000 0.00000 0.40000 ) *
        25) ENV > -0.7175 45   0.000 II ( 0.00000 1.00000 0.00000 0.00000 ) *
      13) SOC > 1.4075 5   6.730 II ( 0.40000 0.60000 0.00000 0.00000 ) *
     7) ENV > 1.076 8   8.997 I ( 0.75000 0.25000 0.00000 0.00000 ) *
```

Figure 9.6 Properties of classification tree model shown in Figure 9.5.

Based on the tree model (Figure 9.5), it is reasonable to classify companies into three main clusters (Terminal node I forms the 'Leader'; all of the terminal nodes II combine to form the 'Average'; while all terminal nodes III combine to form the 'Laggard'). Users of KLD can now use the classification tree model (Figure 9.5) to complement their analysis by straightforward data processing (standardising data using mean and standard deviation of ENV, SOC and GOV that are given in section 9.3.1) and following the splits along the tree to classify companies based on ESG performance.

9.4 Generic regression tree model

The classification tree model (see Figure 9.5) is developed based on KLD data. This section offers a generic model to assist in the classification of companies accounting for ESG performance, consistency in ESG performance and data trend. This is discussed here.

9.4.1 Regression tree model preliminaries

Based on anecdotal evidence and interviews, the current method used by practitioners to distinguish the overall sustainability performance of companies is by analysing the mean value of some form of ESG criteria (ENV, SOC, GOV or combined ESG). This might not be adequate, because there are other underlying properties in the ESG data set which are arguably important as well; for example, consistency in performance and data trend (whether ESG performance is improving or declining over a certain period).

Consider two different data sets (Company A and Company B) used here for illustration (see Appendix S, Table S1). The range of ESG values are measured between 0 and 100 (higher ESG value is representative of better sustainability performance) over a period of 10 years. If a practitioner uses the mean value of ESG solely to represent overall sustainability performance, the practitioner would be assuming that both Company A and Company B are of equal standing because both give the same mean value of 16.1. This does not really allow for a robust differentiation of companies' overall sustainability performance.

An important property to also consider in the data set is the consistency of ESG values for both companies, Company A and Company B. Consistency of ESG values can be measured by the standard deviation. The higher the standard deviation, the lesser the consistency. From Figure 9.7, the standard deviation of ESG for Company A is 25.2 while standard deviation of ESG for Company B is 19.3. This suggests that sustainability performance is less consistent for Company A compared to Company B.

Also, from Figure 9.7, it is obvious that the ESG values for both Company A and Company B appear to be trending in an opposite direction. Company B appears to be showing promising results (where ESG values are improving) whereas Company A is showing signs of deteriorating sustainability performance (where ESG values are declining). The slope of the line of best-fit for the data sets of both companies, Company A and Company B, would give an insight to the rate of ESG improvement (or decline). This rate of ESG improvement is representative of the data trend. The rate of ESG improvement for company B is 5.75/year whereas the equivalent value for company A is -6.44/year.

Therefore, relying just on the mean value of ESG is less helpful, as two other properties – namely, consistency and data trend – are 'hidden' from practitioners.

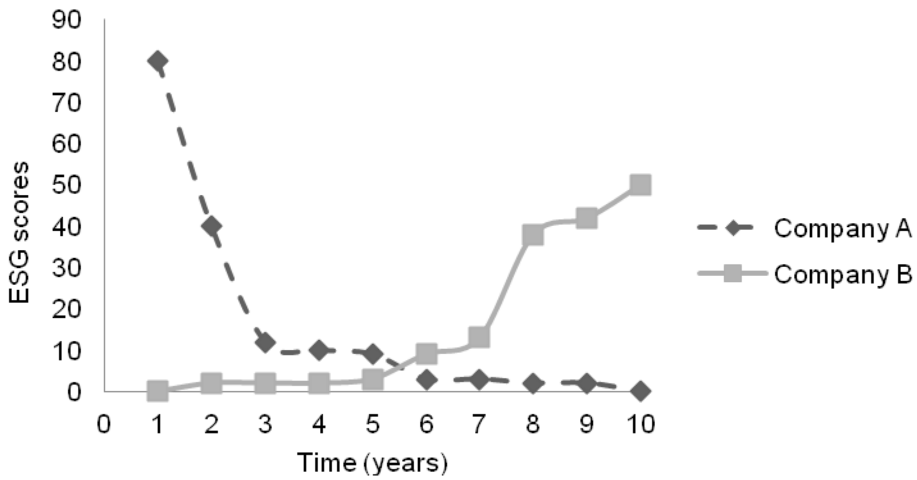


Figure 9.7 ESG data for Company A and B.

It is argued here that because all three properties (mean of sustainability performance, consistency and data trend) are equally useful in helping to differentiate a company's overall sustainability performance, they should be accounted for.

9.4.2 Criteria

Three main criteria (representing the aforementioned three properties - mean of sustainability performance, consistency and data trend) are proposed here for a regression tree model which can be used to classify companies in a more robust manner. These criteria should be normalised to account for the wide range of scoring scales used across different ESG databases (see Chapter 2 for listing of different ESG scoring tools). The three predictor criteria are:

(a) *ESG*. The *ESG* criterion represents the mean of sustainability performance. The *ESG* criterion is calculated by dividing the mean value of ESG (derived from the summation of ENV, SOC and GOV) of a company by the largest mean value of ESG for the pool of companies compared.

(b) *STD*. The *STD* criterion represents consistency in sustainability performance. It is given as 1 – normalised standard deviation. Normalised standard deviation can be derived by dividing standard deviation of ESG for a company with the largest standard deviation for the pool of companies compared.

(c) *GRAD*. The *GRAD* criterion represents the data trend. The rate of ESG improvement can be obtained by taking the slope of the line of best-fit in an ESG and time plot. *GRAD* is calculated by dividing the rate of ESG improvement of a company by the largest rate of ESG improvement for the pool of companies compared.

In order to evaluate the overall sustainability performance of companies accounting for *ESG*, *STD* and *GRAD,* a response criterion, TARGET, is used. TARGET is calculated as a function of *ESG*, *STD*, *GRAD* as follows:

$$\mathrm{TARGET} = 10ESG + 10STD + 10GRAD \tag{9.7}$$

In Equation (9.7*), ESG, STD* and *GRAD* are all given scales from 1 to 10, implying that they are treated as having equal importance. A linear function is used because it is straightforward and easy to understand. The weights could be altered to reflect differences in priorities; however, doing so may change the configuration of the regression tree model advanced in this chapter.

9.4.3 Sample training data

Sample or test sets of data are used to develop the relationship between TARGET and the predictor criteria (*ESG, STD* and *GRAD*). The (0,1) ranges for the criteria are interpreted as follows:

- *ESG*. A value of 1 implies that a company has the highest mean value of ESG within the pool compared.
- *STD*. A value of 1 implies that a company has the highest consistency (lowest standard deviation within the pool compared).
- *GRAD*. A value of 1 implies that a company has the best rate of ESG improvement. Negative *GRAD* values are assumed to be zero. That is to say, no credit is given for deteriorating ESG performance.

There is no 'hard and fast rule' when it comes to determining the size of the sample or test sets of data for constructing a regression tree, although, ideally, the sample data should represent all possible relationships between the response and predictor criteria.

For the regression tree model presented in this chapter, a total of 1320 sample training data is used to represent the relationship between the response criterion (TARGET) and the predictor criteria (*ESG*, *STD* and *GRAD*). This data set represents most combinations possible and is large enough for constructing a regression tree.

9.4.4 Regression tree model development

Tree models are constructed using binary recursive partitioning where data are successively split along the coordinate axes of the predictor criteria (*ESG*, *STD* and *GRAD*) so that, at any given node, the split which maximally distinguishes TARGET in the left and right branches is selected. Splitting is carried out until nodes are 'pure'; that is, all members have the same properties, or if there is too few data to merit further subdivision (Crawley, 2007, pp. 686-687). Every possible split for each predictor criterion is assessed in turn and the split producing the highest deviance in TARGET is chosen. The node deviance is given as (Breiman et al., 1984):

$$\text{Deviance} = \sum_j \left(\text{TARGET}_j - \mu_{[j]}\right)^2 \tag{9.8}$$

where $\mu_{[j]}$ refers to the mean of all values of TARGET assigned to node j. The squares are added over all the nodes. Note that the definition of node deviance here differs from a classification tree analysis.

Figure 9.8 depicts the twelve-node regression tree model created in the R program from the 1320 sample training data set. The terminal nodes of the tree represent TARGET values. Figure 9.9 gives the R output code, which explains the properties of the suggested regression tree model. Note that a regression tree output is slightly different compared to a classification tree output (see Figure 9.6). The layout of the code is in the following order: node), split, n, deviance, TARGET. In Figure 9.9, the terminal nodes, totalling 12, are denoted by asterisk. Deviance is calculated from Equation (9.8). The largest value of TARGET is found to be 26 located at node 15, while the lowest value is 7 located at node 8.

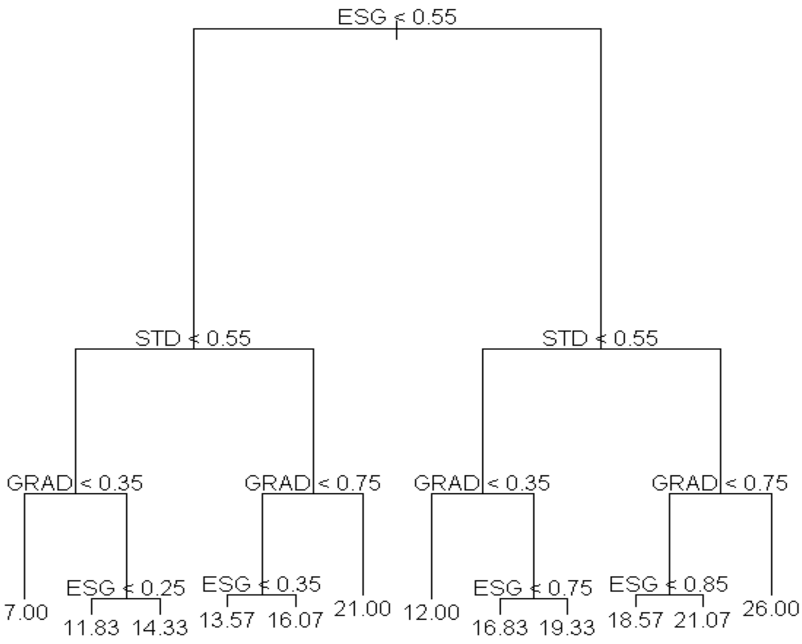


Figure 9.8 Twelve-node regression tree model.

```
1) root 1320 30800.0 16.41
  2) ESG < 0.55 660 11270.0 13.91
    4) STD < 0.55 360  3908.0 11.75
      8) GRAD < 0.35 90   420.0  7.00 *
      9) GRAD > 0.35 270   780.0 13.33
       18) ESG < 0.25 108   123.0 11.83 *
       19) ESG > 0.25 162   252.0 14.33 *
    5) STD > 0.55 300  3675.0 16.50
     10) GRAD < 0.75 210   651.4 14.57
       20) ESG < 0.35 126   222.9 13.57 *
       21) ESG > 0.35 84   113.6 16.07 *
     11) GRAD > 0.75 90   420.0 21.00 *
  3) ESG > 0.55 660 11270.0 18.91
    6) STD < 0.55 360  3908.0 16.75
     12) GRAD < 0.35 90   420.0 12.00 *
     13) GRAD > 0.35 270   780.0 18.33
       26) ESG < 0.75 108   123.0 16.83 *
       27) ESG > 0.75 162   252.0 19.33 *
    7) STD > 0.55 300  3675.0 21.50
     14) GRAD < 0.75 210   651.4 19.57
       28) ESG < 0.85 126   222.9 18.57 *
       29) ESG > 0.85 84   113.6 21.07 *
     15) GRAD > 0.75 90   420.0 26.00 *
```

Figure 9.9 R output code.

9.4.5 Tree pruning

As part of the regression tree methodology, ‘pruning’ is used to reduce the number of terminal nodes. The plot of total deviance (defined as the sum of all node deviances) against tree size is shown in Figure 9.10, and can be used to guide the pruning process. As the tree size grows to more than six terminal nodes, the tree deviance continues to decrease but at a much reduced rate. The tell-tale sign as to whether the tree size is satisfactory is based on the TARGET values at the terminal nodes. If TARGET values (in parentheses) are too close to each other, for example node 11 (21.00) and node 29 (21.07) in the twelve-node regression tree model, this may provide an indication that pruning is needed.

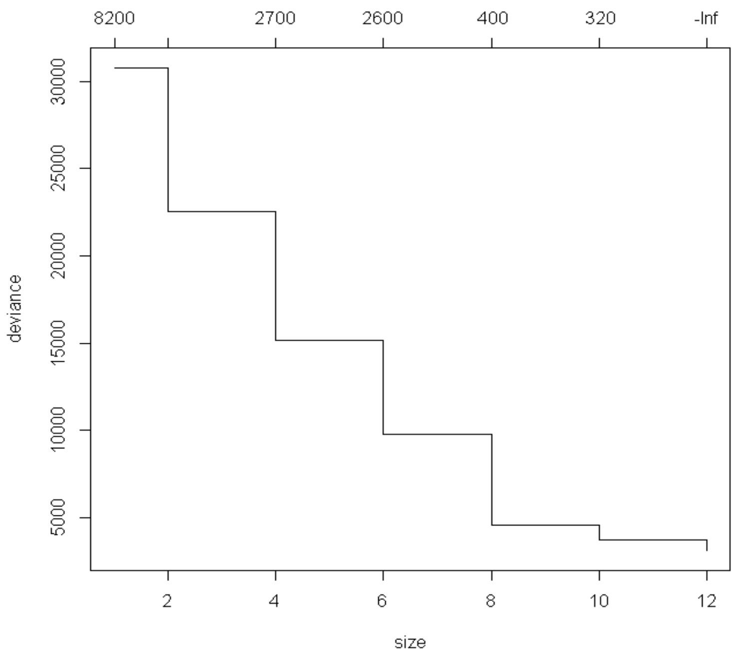


Figure 9.10 Total deviance versus tree size.

More than eight terminal nodes are not examined because doing so diminishes the usability of the tool. After 'pruning' trials with tree sizes of ten, eight, six, and four, it is seen that using six as the number of terminal nodes appears reasonable. The model shown in Figure 9.11 with six terminal nodes is satisfactory because the TARGET values at the terminal nodes are not close to each other.

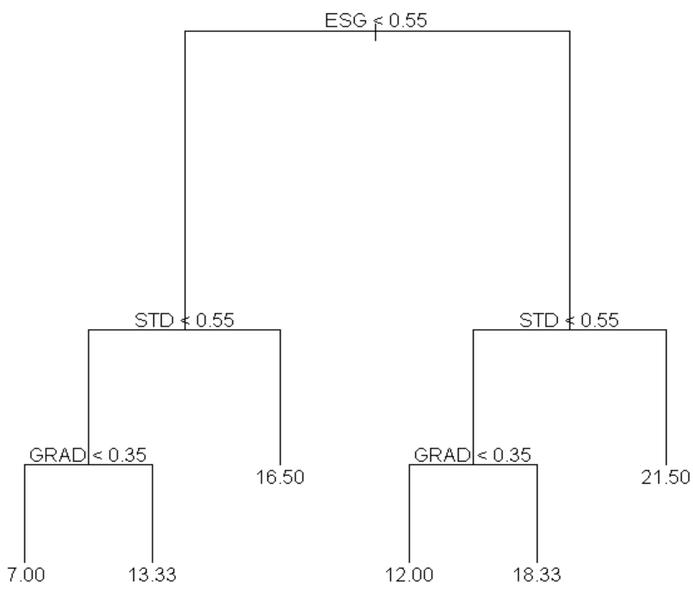


Figure 9.11 Six-node regression tree model.

9.4.6 Classification results

The six terminal nodes represent six different clusters, namely P1, A1, A2, A3, E1 and E2. The properties of these clusters (i.e. the mean and standard deviation of each criterion - TARGET, *ESG*, *STD* and *GRAD*) are shown in Table 9.3. P1 is also referred to as the 'Low Performance' cluster, A1, A2 and A3 are referred to as the 'Mid-Range' clusters while E1 and E2 are referred to as the 'High Performance' clusters. Collectively, 'Low Performance', 'Mid-Range' and 'High Performance' are defined as parent clusters in this chapter.

Clusters	**P1**	**A1**	**A2**	**A3**	**E1**	**E2**
TARGET	7	12	13.3	16.5	18.3	21.5
	2.2	2.2	1.7	3.5	1.7	3.5
ESG	0.3	0.8	0.3	0.3	0.8	0.8
	0.14	0.14	0.14	0.14	0.14	0.14
STD	0.2	0.2	0.4	0.8	0.4	0.8
	0.08	0.08	0.14	0.14	0.14	0.14
GRAD	0.2	0.2	0.66	0.55	0.66	0.55
	0.08	0.08	0.19	0.29	0.19	0.29

Table 9.3 Summary of the resulting six clusters. The columns represent the six clusters (P1, A1, A2, A3, E1, and E2). The rows represent the properties of these clusters *ESG, STD* and *GRAD* (mean upper value; standard deviation lower value)

The properties of these six clusters (P1, A1, A2, A3, E1 and E2) are described as follows:

Low Performance:
P1: TARGET = 7. Comparatively, this is probably the worst performing cluster with *ESG*, *STD* and *GRAD* all towards the lower end - *ESG* (0.3), *STD* (0.2) and *GRAD* (0.2). Companies that fall within this cluster are less favourable to an investor who places high importance on corporate social responsibility.

Mid-Range:

A1: TARGET = 12. *ESG* is high (0.8) but *STD* is low (0.2). This implies that, although sustainability performance is good, it is less consistent. The rate of ESG improvement represented by *GRAD* is also not very convincing with only a value of 0.2 (similar to P1).

A2: TARGET = 13.3. This cluster has low *ESG* (0.3) similar to P1 but has a high *GRAD* (0.66). This implies that, although sustainability performance is low, companies within this cluster are showing progressive improvement. *STD* value is 0.4.

A3: TARGET = 16.5. The companies in this cluster have higher TARGET values (compared to those in A1) because they are able to demonstrate better consistency. *STD* is 0.8. In addition, this cluster shows promising results with a *GRAD* value of 0.55.

High Performance:

E1: TARGET = 18.3. This cluster has a high *ESG* (0.8) and a commendable *GRAD* value (0.66), although, comparing to A3, *STD* is about 50% lower, implying lesser consistency.

E2: TARGET = 21.5. Companies that fall within this cluster are perhaps the most desirable to socially responsible investors. They are able to not only demonstrate good sustainability performance given by a high *ESG* (0.8) but also a high level of consistency, *STD* (0.8). Therefore, companies which fall within this cluster should be given most attention.

9.4.7 Validation

To validate the accuracy of the regression tree model (in Figure 9.11), 25 random samples were selected from the NYSE. For each of these samples, *ESG*, *STD* and *GRAD* are determined (as described under section 9.4.2). TARGET is calculated based on Equation (9.7), while predicted TARGET is obtained by following the splits along the branches in the six-node regression tree model (in Figure 9.11). The difference (%)

between TARGET and predicted TARGET shown in Table 9.4 indicates that the six-node regression tree model is satisfactory. Of the 25 samples, 16 have a percentage difference of less than 10% between predicted TARGET and TARGET values, while the remaining nine have a difference between 10% and 18.2%. Although there are percentage differences larger than 18%, there are no misclassification errors; that is, all companies are classified into the same parent clusters ('Low Performance', 'Mid-Range' and 'High Performance') regardless of whether TARGET or predicted TARGET is used. This justifies the reliability of the regression tree model in Figure 9.11.

TARGET	***ESG***	***STD***	***GRAD***	**Predicted TARGET**	**Difference (%)**
21.33	1.00	0.35	0.78	21.5	0.79
20.27	0.74	0.53	0.76	21.5	6.09
21.72	0.79	0.41	0.97	21.5	-1.02
14.69	0.28	0.53	0.66	16.5	12.32
15.16	0.38	0.47	0.67	16.5	8.84
17.11	0.05	0.88	0.78	16.5	-3.55
15.41	0.36	1.00	0.18	16.5	7.09
14.76	0.50	0.35	0.62	16.5	11.80
14.32	0.41	0.47	0.55	16.5	15.24
13.96	0.29	0.35	0.75	16.5	18.17
15.03	0.00	0.88	0.62	16.5	9.78
16.09	0.17	0.71	0.73	16.5	2.53
17.15	0.09	0.82	0.80	16.5	-3.79
14.46	0.49	0.53	0.43	16.5	14.11
15.43	0.00	0.88	0.66	16.5	6.94
22.86	0.90	0.41	0.97	21.5	-5.95
14.9	0.00	1.00	0.49	16.5	10.74
14.80	0.29	0.71	0.48	16.5	11.49
15.97	0.04	0.77	0.79	16.5	3.32
15.35	0.16	0.77	0.61	16.5	7.49
18.14	0.69	0.29	0.83	18.33	1.05
14.99	0.21	0.53	0.76	16.5	10.09
16.21	0.20	0.71	0.71	16.5	1.78
15.17	0.00	0.71	0.81	16.5	8.78
14.58	0.21	0.77	0.48	16.5	13.16

Table 9.4 Validation of 6-node regression tree model for a random sample of 25 companies.

The main advantage of this generic regression tree model is its flexibility – practitioners can use it to classify companies assessed with different ESG scoring tools. In the future, practitioners may also wish to conduct the analysis of sustainability performance by controlling for industry sectors, size or age of companies.

9.5 Conclusion

In this chapter, two contributions are made to the methodological spectrum of SRI. It first introduces a model to classify companies as either a 'Leader', 'Average' or 'Laggard' based on their ESG performance. Both hierarchical clustering and classification tree techniques are used to construct this. Secondly, a generic regression tree model (see Figure 9.11) is built based on three proposed criteria, namely *ESG* – a measure of sustainability performance, *STD* – a measure of performance consistency, and *GRAD* – a measure of data trend. Validation was done against 25 sample companies selected from the NYSE and the regression tree model was found to be reliable. For both models, the calculations can be performed in a few steps, requiring straightforward data processing which the practitioner already has in hand.

CHAPTER 10 – MODELLING THE RELATIONSHIP BETWEEN SUSTAINABILITY MATURITY LEVELS, SUSTAINABILITY PERFORMANCE AND FINANCIALS

10.1 Introduction

Current corporate SRTs (frameworks; standards; scores and indices) have been critiqued for their inability to capture nuances in sustainability practices. As a result, the distinction between real leaders and laggards is often blurred. This argument is also in line with scholarly literature (see Dumay et al., 2010 and Moneva et al., 2006 discussed in Chapter 2) claiming that corporate SRTs are merely encouraging a 'managerialist' approach and do not assist a company in answering the question of 'How quickly it is approaching sustainability?' or 'What is the benchmark of best practice?' (Isaksson and Steimle, 2009, p. 179)

There is an urgent need for a framework to better understand the distinction in sustainability practices adopted by the leaders and laggards. The ontological contribution presented in Chapter 9 helps to streamline existing terminology where a distinction is made between three clusters of companies, namely 'Leader', 'Average' and 'Laggard', based on their ESG scores. This chapter closes the gap further by modelling the link between these different clusters of companies (see Chapter 9) and sustainability maturity levels (SML) assessed with four criteria: sustainability reporting (SR); stakeholder engagement (SE); business strategy (BS); and internal processes (IP).

Results from the maturity level assessment of these companies then serve as inputs into a Bayesian belief network (BBN) to capture the relationship between sustainability maturity levels and financial performance. BBN has an advantage compared to traditional statistical tools as it helps with reasoning under uncertainty and has the ability to more naturally predict causal relationships. The results from the first BBN model indicate that, when both SR and IP are towards the higher or lower ends of sustainability maturity levels (ad hoc and integrated), there is a larger negative effect on financial performance compared to average sustainability maturity levels (defined or managed). The remaining criteria, namely SE and BS, did not demonstrate any prominent effect on financial performance across different maturity levels. Consistent with this finding, the second BBN model shows that there is a higher probability of a below average financial performance when maturity index (MI) is low (ad hoc). However, a higher MI (integrated) does not necessarily lead to better financial performance.

This chapter first presents some background information on maturity levels and introduces the concept of BBN. Details of the sustainability maturity model including the description of the four distinctive levels (ad hoc, defined, managed and integrated) and the selected criteria (SR, SE, BS and IP) are presented. Sample companies from the NYSE are used to authenticate this model. The relationship between sustainability maturity levels and financial performance are then presented in the Results section.

10.2 Background

This section discusses the origin of the maturity level concept and provides some necessary background information on BBN.

10.2.1 Maturity levels

The origin of project management maturity can be traced back to the Capability Maturity Model (CMM) first developed by the Software Engineering Institute (SEI) at Carnegie Mellon University. Reasons cited for using maturity models include the ability to identify and understand key practices that enhance effectiveness of communication, help to manage great complexities, obtain consistent results, achieve stringent targets within budget as well as identify key practices that need to be embedded to achieve higher maturity levels. The project management fraternity has since actively demonstrated an interest in the development of tools revolving around project management maturity, given the growing base of evidence that higher levels of maturity improves organisational performance (Grant and Pennypacker, 2006). Today, more than 30 different project management maturity tools are available in the market. Arguably, the most prominent among them is the Portfolio, Programme and Project Management Maturity Model (P3M3) introduced by the Office of Government Commerce (P3M3, 2013). This model identifies five levels of progressive maturity: initial process, repeatable process, defined process, managed process and optimised process. Another example is the Project Management Maturity Model (PMMM) which adopts a two-dimensional framework where one dimension reflects on a five level maturity (ad hoc, planned, managed, integrated and adaptive) and the other depicts the nine knowledge areas of project management in accordance to the Project Management Body of Knowledge (PMBOK) - integration, scope, time, cost, quality, human resources, communications, risk and procurement (Vergopia, 2008).

10.2.2 Bayesian belief network (BBN)

BBN has been used for modelling works because of its ability to reason under uncertainty (Fan and Yu, 2004; Bouissou et al., 1999; Fenton and Neil, 1999; Ziv and Richardson, 1997). Much of the detailed mathematical development and groundwork for BBN has been covered in a few technical reports (see Heckerman, 1995; Hesar et al., 2012; Lenaburg, 2007) and will not be discussed here. Some of its advantages include overcoming inherent limitations of the combinatorial dependability methods such as fault trees and its ability to more naturally predict common-cause failures compared to reliability block diagrams (Sigurdsson et al., 2001). Also, there is no minimum sample size required to carry out the analysis (Uusitalo, 2007). BBN is able to show good prediction accuracy even with small sample sizes (Uusitalo, 2007).

Broadly, BBN refers to an acyclic graph with a set of conditional probability tables associated with each node. The nodes that exist in BBN represent the criteria (see Table 10.4) where the states are usually discretised. The arrows or arcs represent the causal relationships between two nodes (Fan and Yu, 2004). According to Sigurdsson et al. (2001), BBN involves three stages. The first stage comprises problem structuring where the aim is to be able to identify relevant criteria and express them statistically. The second stage is ‘instantiation’ where conditional probabilities are specified. The conditional probability tables are filled based on value judgement or experience. In cases where root causes are unknown, evenly distributed probabilities are assigned. The third stage is 'inference': that is, as and when new evidences are gathered, they can be entered into the BBN model and probability values of the nodes can be updated accordingly. Various softwares exist to model Bayesian networks such as GeNIe, Smile, Netica, Hugin and dVelox among others.

10.3 Sustainability maturity model

This section discusses the four maturity levels proposed (ad hoc, defined, managed and integrated) as well as the criteria selection. The main characteristics at each level are defined as follows:

Level 1 – Ad hoc

- No standard process in place to track sustainability outcomes
- Reactive approach is clearly dominant
- Lack synchronisation
- Lack awareness.

Level 2 – Defined

- Has a plan to identify areas of concern
- Some evidence that sustainability-related framework or documentation is in place
- Very localised efforts.

Level 3 – Managed

- Has a clearer structure in terms of sustainability management
- Coordination exists to ensure consistency in the delivery of sustainability outcomes
- Monitor and control performance in quantitative terms
- Establish goals, analyse measurements and make adjustments to processes to maintain performance.

Level 4 – Integrated

- Sustainability initiatives/processes are well-integrated
- Shared goals and vision with management to promote continuous process improvement
- Proactive management to identify potential problems and prevent them from re-occurring
- Close-interaction exists between departments.

Four criteria, namely sustainability reporting (SR) (Siew et al., 2013; Jones et al., 2007; Hahn and Kühnen, 2013; Yusoff et al., 2013), stakeholder engagement (SE) (Berman et al., 1999; Moneva et al., 2007; Hillman and Keim, 2001), business strategy (BS) (Vickery et al., 1993; Zahra and Covin, 1993; Gupta and Somers, 1996) and internal processes (IP) (Sharma, 2005; Corbett et al., 2005; Melnyk et al., 2003; Watson et al., 2004) are selected as they are deemed to be 'material' (see GRI, 2011) to companies. Also see the frameworks proposed by Cagnin et al. (2013) as well as Baumgartner and Ebner (2010) which correspond to the criteria proposed here. More specific guidelines used in the assessment of maturity levels across these four criteria are provided in Table 10.1. Generally, SR deals with the process of communicating and sharing sustainability information/achievements with stakeholders (Gray et al., 1987). SE refers to how proactive a company is in understanding and managing issues that are important to stakeholders (Owen et al., 2001). BS is used in the same sense as Teece (2010) but with a particular emphasis on whether sustainability has been embedded as part of a company's overarching goal. IP refers to a company's initiative in regulating its business processes by ensuring there are proper sustainability benchmarks in place; for example, the adoption of relevant sustainability standards (see Chapter 2). Scores are given to each criterion depending on how well a company fits the maturity level descriptions.

Symbol	Criterion	Score	Descriptions
SR	Sustainability reporting/ Communication	0 or 1	No reporting/Poor reporting – does not address anything material.
		2 or 3	Important areas identified but reporting is mostly qualitative.
		4 or 5	Quantitative reporting on sustainability performance and improvements are suggested.
		6 or 7	Sustainability report is of high quality with evidence of assurance from third-party.
SE	Stakeholder engagement	0 or 1	No evidence of active engagement.
		2 or 3	States that engagement process is in place but does not sufficiently address stakeholders' concerns.
		4 or 5	Uses a variety of tools for engagement - sustainability reports, corporate websites and annual meetings. Some evidence that company is doing something to address concerns.
		6 or 7	Board oversees sustainability issues and strong evidence that stakeholders' concerns are addressed.
BS	Business strategy	0 or 1	No evidence that sustainability is articulated as a core strategy or mission statement.
		2 or 3	Defined targets for sustainability.
		4 or 5	There are specific departments overseeing sustainability issues/achievement of goals.
		6 or 7	Philosophy or vision statement incorporates sustainability. Not just financial gains.
IP	Internal processes	0 or 1	Does not adopt any sustainability-related standards.
		2 or 3	Acknowledges importance of some standard processes/certification (i.e. ISO 14001) but not fully present in all facets of business.
		4 or 5	Most internal processes are based on standards/regulations.
		6 or 7	Sustainability is fully incorporated into internal business processes and company actively participates in setting regulatory standards.

Table 10.1 Maturity level descriptions.

It is proposed that the link between different clusters (‘Leader’, ‘Average’, ‘Laggard’) and sustainability maturity levels can be represented by the model shown in Figure 10.1. According to this model, the ‘Laggard’ cluster is expected to have either an ad hoc or defined maturity level while the ‘Average’ cluster is expected to depict characteristics of either a defined or managed maturity level. The ‘Leader’ cluster on the other hand is expected to demonstrate a visible and integrated approach towards sustainability. If this model is correct, it might imply that the adoption of higher maturity levels would lead to better sustainability performance.

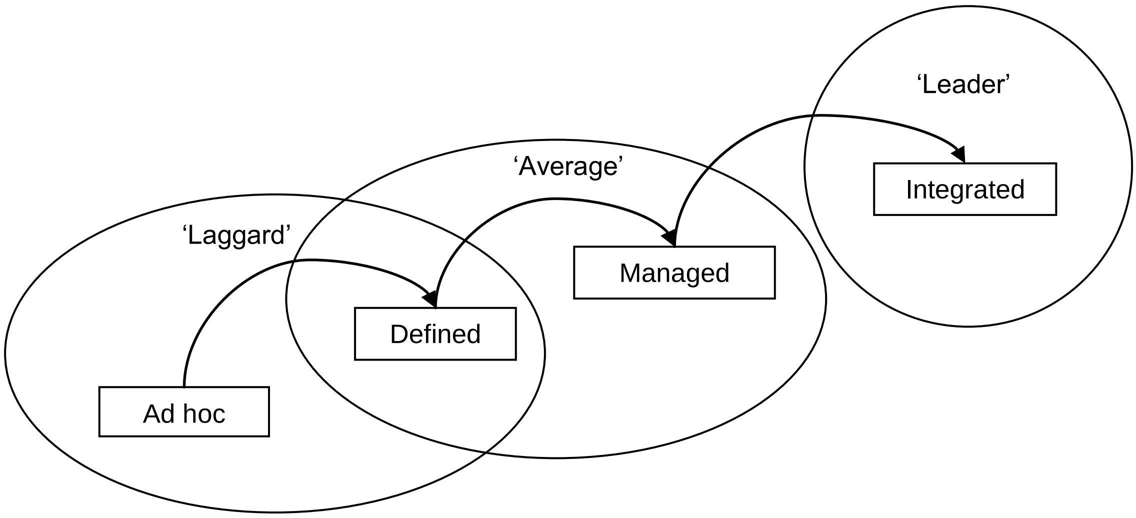


Figure 10.1 Model linking different clusters (‘Leader’, ‘Average’ and ‘Laggard’) with overall maturity levels.

10.3.1 Validation

To test the validity of the model (Figure 10.1), a sample of 50 companies composed of a mixture of the ‘Leader’, ‘Average’ and ‘Laggard’ clusters are selected from the New York Stock Exchange (NYSE). The maturity levels of each company are assessed based on the four criteria listed in Table 10.1.

Maturity levels are determined by comparing each criterion score (z) with the scoring scale as shown in Table 10.2.

Maturity level	Scoring scale
Ad hoc	$0 \leq z \leq 1$
Defined	$1 < z \leq 3$
Managed	$3 < z \leq 5$
Integrated	$z > 5$

Table 10.2 Mapping of scores to maturity level.

Based on the analysis, the mean of each criterion (SR, SE, BS and IP) for the different clusters ('Leader', 'Average' and 'Laggard') are outlined in Table 10.3.

Clusters	SR	SE	BS	IP
'Leader'	6	5.88	5.88	6.75
'Average'	3.45	2.75	3.77	3.87
'Laggard'	2.18	2.09	1.36	1.82

Table 10.3 Mean of each criterion (SR, SE, BS and IP) for different clusters.

It is observed that all criteria (SR, SE, BS and IP) for the 'Leader' cluster correspond to an integrated maturity level (between 5.88 and 6.75). Criteria SR, BS and IP of the 'Average' cluster correspond to a managed maturity level except for SE (2.75), while all criteria of the 'Laggard' cluster correspond to a defined maturity level. The results therefore appear to authenticate the model proposed in Figure 10.1: that is, as sustainability maturity level increases, sustainability performance increases.

10.4 Bayesian belief network models

This section discusses the data set used and the two learning algorithms, namely greedy thick thinning (GTT) and path condition (PC) available in the GeNIe 2.0 software. BBN is useful as it can be updated as and when new insights or more data for any of the criteria (see Table 10.1) are gathered.

Summary statistics (mean, variance and standard deviation) of the samples used for the analysis is provided in Table 10.4. Two BBN models are presented in this chapter. The first BBN model examines the relationship between maturity levels of the individual criteria (SR, SE, BS, IP) with financial performance represented by the return on equity measure (ROE) while the second BBN model examines the relationship between MI (combination of SR, SE, BS and IP) with ROE. Other criteria are also included in the analysis. ENV, SOC and GOV scores are from the KLD database (KLD, 2013). Data for SIZE, GROWTH and ROE are obtained through authorised access to Compustat-Historical database (Compustat, 2013). SIZE is defined as log of assets while GROWTH is defined as percentage change in earnings per share (EPS). The dataset for a 15 year period (1997-2011) is lumped together. The states for each criterion are then determined based on their averages. For example, the average SIZE of the 50 sample companies is 3.82. This value is used to create two states for SIZE (one below 3.82; the other above 3.82). For MI, the states which reflect on the four different maturity levels are determined based on the scoring scale proposed in Table 10.1. Because MI is the combination of all four criteria, the summation of the lower end and higher end scores are taken into account in developing its continuous scale. The process of creating the states is known as discretisation. The discretisation of the criteria is shown in Table 10.5 (see Uusitalo, 2007, p. 314) for further discussion on discretisation in BBN.

Criterion	**Mean**	**Variance**	**StdDev**
ENV	0.62	0.33	0.57
SOC	1.23	4.33	2.08
GOV	-0.51	0.32	0.57
SR	3.58	5.11	2.26
SE	3.10	8.62	2.94
BS	3.58	8.25	2.87
IP	3.88	7.25	2.69
MI	14.20	89.80	9.48
Age	61.22	1937.64	44.02
SIZE	3.82	0.89	0.94
GROWTH	-0.21	0.99	0.99
ROE	0.11	0.01	0.11

Table 10.4 Summary statistics of NYSE samples.

Criterion	Number of states	Discretisation
ENV	2	≤ 0.62; > 0.62
SOC	2	≤ 1.23; > 1.23
GOV	2	≤ -0.51; > 0.51
SR	4	0 ≤ SR ≤ 1; 1< SR ≤ 3; 3 < SR ≤ 5; SR > 5
SE	4	0 ≤ SE ≤ 1; 1< SE ≤ 3; 3 < SE ≤ 5; SE > 5
BS	4	0 ≤ BS ≤ 1; 1< BS ≤ 3; 3 < BS ≤ 5; BS > 5
IP	4	0 ≤ IP ≤ 1; 1< IP ≤ 3; 3 < IP ≤ 5; IP > 5
MI	4	0 ≤ MI ≤ 7; 7 < MI ≤ 15; 7 < MI ≤ 23; 23 < MI ≤ 28
Age	2	≤ 61.22; > 61.22
SIZE	2	≤ 3.82; > 3.82
GROWTH	2	≤ -0.21; > -0.21
ROE	2	≤ 0.11; > 0.11

Table 10.5 Discretisation of criteria.

10.4.1 Greedy thick thinning (GTT)

Hesar et al. (2012, p. 249) describe the GTT algorithm as follows:

"It starts off with an empty graph and repeatedly adds the arc that maximally increases the Bayesian metric until no arc addition will result in an increase. Then, it repeatedly removes arcs until no arc deletion will result in an increase in the Bayesian metric."

The objective of GTT is to maximise the Bayesian metric. The Bayesian metric, a measure of how likely it is to observe a set of criteria W in a Bayesian network (BN), is given by Equation (10.1) (Hesar et al., 2012; Lenaburg, 2007):

$$P(W \mid BN) = \prod_{i=1}^{n} \prod_{j=1}^{qi} \frac{\Gamma(N'_{ij})}{\Gamma(N'_{ij} + N_{ij})} \prod_{k=1}^{r_i} \frac{\Gamma(N'_{ijk} + N_{ijk})}{\Gamma(N'_{ijk})} \qquad (10.1)$$

where

n is the number of criteria,

r_i is the number of states of criterion i,

q_i is the number of states of the parent of criterion i, where $q_i = 1$ for a criterion i that has no parent,

N_{ijk} is the number of instances where criterion i take on states k when its parent (a preceding criterion) is in state j,

$$N_{ij} = \sum_{k=1}^{r_i} N_{ijk},$$

N'_{ijk} is the Dirichlet exponent of θ_{ijk}, the probability that criterion i is in state k given that parents of i are in state j, that satisfy (Lenaburg, 2007),

$$P(\Theta_{ij} \mid B_s^h, \xi) = c \prod_k \theta_{ijk}^{N'_{ijk} - 1} \tag{10.2}$$

where

$$\Theta_{ij} = \bigcup_{k=1}^{r_i} \{\theta_{ijk}\},$$

B_s^h is the hypothesis that the data is generated from the structure B_s,

ξ is the current state of information,

c is a normalising constant,

$$N'_{ij} = \sum_{k=1}^{r_i} N'_{ijk}, \tag{10.3}$$

$\Gamma(x+1) = x!$ for all integer values of x

Prior assumptions about the N'_{ijk} Dirichlet exponents need to be made before computing the Bayesian metric. The K2 prior developed by Cooper and Herskovits (1992) is used in this study. K2 is an uninformative prior that assumes all N'_{ijk} exponents are 1. It has been 'considered very successful in producing the most likely structure' (Lenaburg, 2007, p. 56) for the observed data set. The reader is referred to Cooper and Herskovits (1992, p. 322) for details and proof of correctness of the procedure.

10.4.2 Path condition (PC)

The PC algorithm relies on the χ^2-test for independence to derive the conditional interdependencies between criteria. Lenaburg (2007) gives a simple example considering three criteria, A, B, and C which have states a_i, b_j, c_k respectively. Criteria A and C are considered to be independent given criterion B if $P(a_i| b_j, c_k) = P(a_i| b_j)$ for all i, j and k. The undirected links are added between each pair of criteria and, if found to be conditionally dependent, results in what is known as the skeleton. V-structures, which refer to three interconnected nodes via two links, are then identified. The conditional interdependencies and V-structures determine the direction of the link. Directed cycles are usually avoided.

Comparing both algorithms, GTT has a few advantages over PC. First, the PC algorithm will not be able to derive all the direction of the links from the data set (Lenaburg, 2007). Second, the PC algorithm may not be able to produce a correct structure if the sample size is small as this may lead to incorrect interpretations of the independencies of the criteria which results in a wrong skeleton and V-structure (Lenaburg, 2007). Hence, GTT is used in this study.

10.5 Results

Two BBN models are presented here:

- BBN Model 1 (see Figure 10.2) explores the relationship between maturity levels of SR, SE, BS, IP and ROE.
- BBN Model 2 (see Figure 10.3) explores the relationship between MI and ROE.

GeNIe 2, a readily available software which does BBN analysis, enables the estimation of the joint probability distribution of all criteria in a network. For this purpose, GeNIe 2 is used to calculate the probability distribution of ROE given the set of criteria in Table 10.5.

From the BBN models (see Tables 10.6a and 10.6b), two interesting observations are made:

1. There is a higher probability of a below average ROE (probability of 0.67) if SR and IP have low maturity levels (ad hoc).
2. There is a higher probability of a below average ROE (probability of 0.8) if SR and IP have high maturity levels (integrated).

This implies that lower or higher ends of IP and SR maturity levels (ad hoc or integrated) have a negative influence on financial performance. The remaining criteria, namely SE and BS, did not demonstrate any prominent effect on ROE across different maturity levels.

Financial performance	**$0 \leq IP \leq 1$**			
	$0 \leq SR \leq 1$	**$1 < SR \leq 3$**	**$3 < SR \leq 5$**	**SR >5**
ROE – below average (≤ 0.11)	0.67	0.5	0.5	0.5
ROE – above average (> 0.11)	0.33	0.5	0.5	0.5

Table 10.6a Joint probability distribution for BBN Model 1.

Financial performance	**IP > 5**			
	$0 \leq SR \leq 1$	**$1 < SR \leq 3$**	**$3 < SR \leq 5$**	**SR >5**
ROE – below average (≤ 0.11)	0.5	0.5	0.5	0.8
ROE – above average (> 0.11)	0.5	0.5	0.5	0.2

Table 10.6b Joint probability distribution for BBN Model 1.

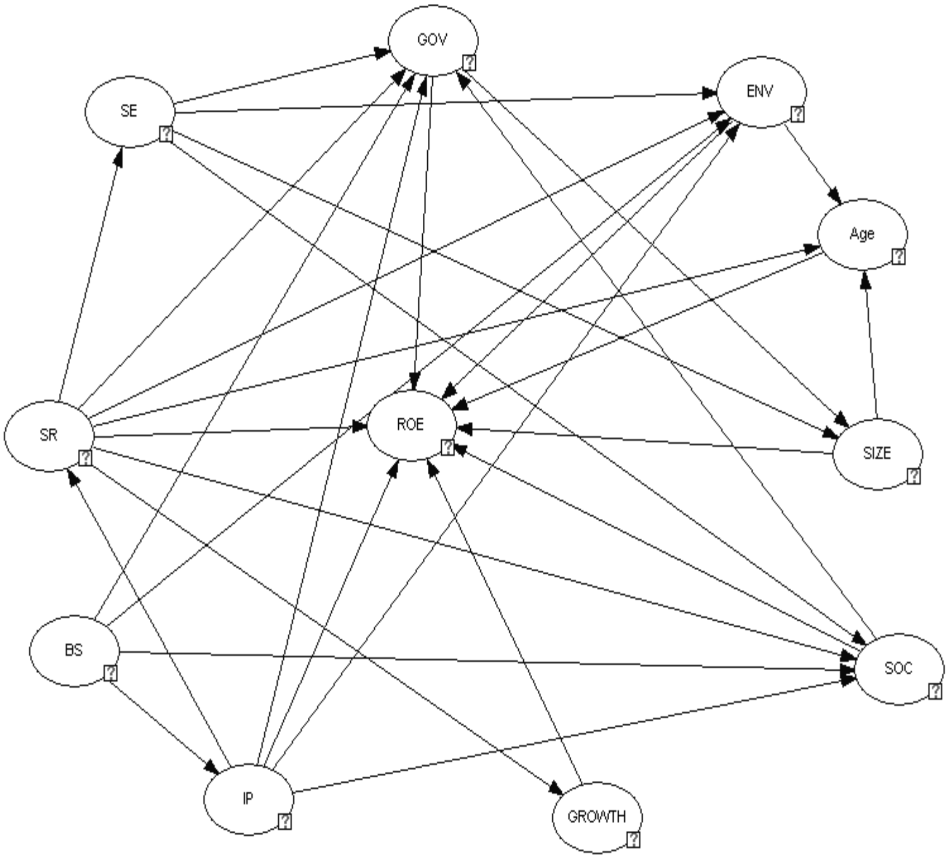


Figure 10.2 BBN Model 1.

From Table 10.7, it is observed that the probability of a below average ROE is higher when MI is low (ad hoc level). Having a higher MI (integrated level) on the other hand does not necessarily lead to a higher ROE.

Financial performance	**0 ≤ MI ≤ 7**	**7 < MI ≤ 15**	**15 < MI ≤ 23**	**23 < MI ≤ 28**
ROE – below average (≤ 0.11)	0.67	0.5	0.5	0.5
ROE – above average (> 0.11)	0.33	0.5	0.5	0.5

Table 10.7 Joint probability distribution for BBN Model 2.

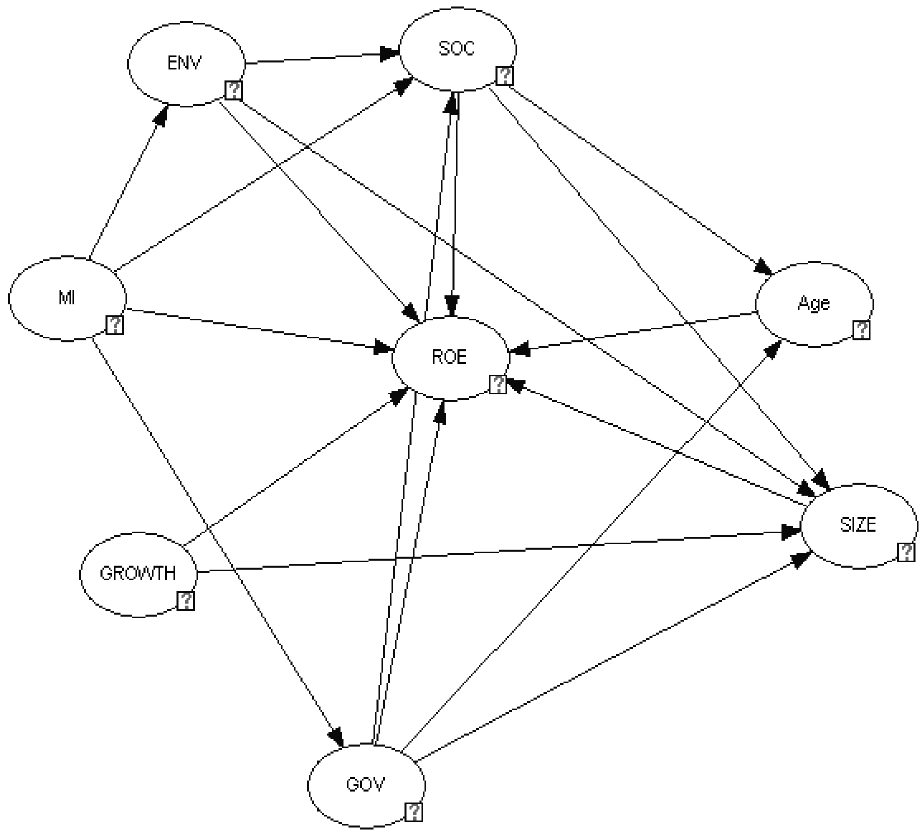


Figure 10.3 BBN Model 2.

10.6 Conclusion

This chapter makes two main contributions. First, it presents a conceptual model to capture the relationship between sustainability maturity levels and different company clusters (based on KLD data) developed in Chapter 9. Sample companies from the NYSE comprising of three clusters (‘Leader’, ‘Average’, ‘Laggard’) were used to test the validity of the model. The model was found to be reliable. Second, it explores the use of BBN to investigate the link between maturity levels of criteria (SR; SE; BS; IP) and financial performance represented by ROE. The findings show that there is a higher probability of obtaining a below average ROE in cases where SR and IP have low maturity levels (ad hoc) and high maturity levels (integrated). The remaining criteria, namely SE and BS, did not demonstrate any prominent effect on ROE across different maturity levels. There is a possibility that companies that overly invest in improving their sustainability practices may be experiencing extra financial burden which affect their profits. Consistent with this conclusion, a low MI (ad hoc) is found to contribute towards a lower ROE. But a high MI (integrated) does not necessarily lead to a higher ROE.

CHAPTER 11 – MEASURING PROJECT SUSTAINABILITY MATURITY LEVEL

11.1 Introduction

In the project management literature, a lot of discussion has revolved around project management maturity models. Project management maturity models are recognised as useful to measure the capabilities of projects as well as implement changes and improvements in a structured manner (Andersen and Jessen, 2003; Jia et al., 2011; Ibbs and Kwak, 2000; Cooke-Davies and Arzymanow, 2003).

Although a number of studies have proposed different project management maturity models, very few have looked into embedding sustainability into project management. Strategic planning for sustainability is mostly confined to an organisational level (Wong et al., 2010). Project management maturity models have the potential to enhance current sustainability practices alongside the traditional focus on cost, time and money. Measuring sustainability maturity levels, however, is complicated as it involves large inconsistencies, high levels of subjectivity and ambiguity. In Chapter 10, a framework linking sustainability maturity levels and different clusters of companies has been established. This chapter now focuses on measuring sustainability maturity levels in projects. Specifically, this chapter makes a contribution by (i) proposing a set of sustainability criteria applicable to project management (integration; scope; cost; human resource management; communication; procurement) and (ii) presenting a fuzzy-based approach to assess project sustainability maturity levels (PSML).

The chapter is organised into three sections. Section 11.2 covers some necessary literature survey on existing project management maturity models. Section 11.3 illustrates the concept of PSML followed by a discussion on fuzzy sets and appropriate linguistic terms to assess PSML. Finally, an example which illustrates the approach is presented in section 11.4.

11.2 Background

A summary of project management maturity models – for example, the Capability Maturity Model (CMM); Berkeley Project Management Process Maturity Model (Berkeley PM^2); Organisational Project Management Maturity Model (OPM3); Project Management Maturity Model (PMMM); Project, Programme and Portfolio Management Maturity Model(P3M3) – is provided here for the reader.

CMM

Established in 1984, CMM was first developed at the Carnegie Mellon University to meet the needs of the Department of Defense for improvement in software (Vergopia, 2008). The root of CMM lies in 'Total Quality' concepts where more mature processes are expected to lead to lesser rework, better quality products and more successful project outcomes. The five maturity levels under CMM, measured using an ordinal scale are outlined as follows (Paulk et al., 1993; Vergopia, 2008; Lianying et al., 2012):

- Level 1: Initial level. The project is described as one lacking a consistent structure to repeat software development and maintenance processes. Such projects usually experience difficulty meeting their commitments (Paulk et al., 1993).
- Level 2: Repeatable level. Primary project management processes are in place to track cost, schedule and functionality. Basic project management guide is available but not used across all projects.
- Level 3: Defined level. A standardised set of project management processes exist and consistently used across all projects. Processes established at this level can be changed as appropriate to increase effectiveness (Paulk et al., 1993).
- Level 4: Managed level. Quantitative measurements (detailed time, cost and other criteria) available for software development. Strong focus on staff training and development. A company-wide database is available to establish a quantitative foundation for evaluating a project's success (Paulk et al., 1993).
- Level 5: Optimising level. The central focus is on continuous process improvement. Weaknesses in project management processes are identified and strengthened on a proactive basis (Paulk et al., 1993).

Under CMM, the term key process areas are defined as 'building blocks' that project management teams should focus on to improve the software process at each maturity level. Key process areas are available across all the different maturity levels except for level 1 (Initial) as shown in Table 11.1 (Weber et al., 1991).

Maturity levels	**Key process areas**
Level 2: Repeatable	Software configuration management, software quality assurance, software subcontract management, software project tracking and oversight, software project planning, requirements management.
Level 3: Defined	Peer reviews, intergroup subordination, software product engineering, integrated software management, training program, organisation process definition, organisation process focus.
Level 4: Managed	Quality management, process measurement and analysis
Level 5: Optimising	Process chance management, technology innovation, defect prevention.

Table 11.1 Key process areas under CMM (Weber et al, 1991).

Berkeley (PM)^2

Kwak and Ibbs (2000) introduce the Berkeley Project Management Process Maturity Model to help measure and benchmark a company's project management maturity level. This model adopts five levels of maturity (ad hoc, defined, managed, integrated and sustained) across nine project management criteria (integration, scope, time, cost, quality, human resource, communication, risk and procurement). The Berkeley PM^2 distinguishes itself from other models in the following ways:

- Actual financial information relating to project management is used as a basis for financial effectiveness.
- Return on investment from project management is derived and forecast is made to determine investment in project management.
- Relationship between effectiveness of project management and project performance is measured.

Kwak and Ibbs (2000) summarise the characteristics of the Berkeley $(PM)^2$ as shown in Table 11.2.

Industries	Collected information	Graphical representation	Deliverables
• Relevant to all types of industries (construction, information management)	• Nine criteria (integration, scope, time, cost, quality, risk, human resource, communication, procurement) • Five phases (initiate, plan, execute, control and close out) • Financial data to calculate return on investment of project management (PM/ROI)	• Five levels of maturity (ad hoc, defined, managed, integrated, sustained) • Project management maturity versus project performance	• Project maturity levels • PM/ROI

Table 11.2 Characteristics of the Berkeley PM^2 (Kwak and Ibbs, 2000)

OPM3

OPM3 developed by the Project Management Institute (PMI) is a model which emphasises on the application of knowledge, skills, tools and techniques to project, program as well as portfolio management processes to achieve the aims of a company (Milosevic and Patanakul, 2005; Vergopia, 2008; Lianying et al., 2012; Hillson, 2003; Guangshe et al., 2008).

OPM3 consists of the following three interlocking elements:

- Knowledge – provides users with more than 100 best-in-class project, program and portfolio management processes
- Assessment – allows a company to evaluate its current capabilities and identify project, program and portfolio management processes which need improvement
- Improvement – from the assessment, a map of the steps required to achieve higher levels of maturity in project, program and portfolio management processes is developed.

Further details on the distinction between project, program and portfolio management processes are provided by Guangshe et al., (2008). Thiry and Deguire (2007) criticise OPM3 for making a weak attempt at distinguishing the project management and program management modules, stating that both modules appear similar in the model.

PMMM

The PMMM model has been criticised for its generality compared to the other maturity models. For PMMM, the lower maturity level must be met before a higher level of maturity is attained. In a similar fashion, its five maturity levels are defined as (Vergopia, 2008):

- Level 1: Common knowledge. The company has a good understanding of the basic knowledge of project management and relevant terminology.
- Level 2: Common processes. Common processes are clearly defined within the company. Project management processes are used in line with other improvement methods such as total quality management (TQM).
- Level 3: Singular methodology. A realisation that synergistic effects are beneficial to the company. All company methodologies are combined and centred on project management.
- Level 4: Benchmarking. The company knows what to benchmark and how to benchmark.
- Level 5: Continuous improvement. The company constantly uses benchmark data to analyse and improve results.

P3M3 Model

The three modules available under P3M3 are project, programme and portfolio (P3M3, 2013). P3M3 uses a five level maturity model (Level 1: Awareness; Level 2: Repeatable; Level 3: Defined; Level 4: Managed; Level 5: Optimised) and seven criteria (management control; benefits management; financial management; stakeholder engagement; risk management; organisational governance; and resource management) which can be assessed under all three modules. A series of generic questions available under each module are used to guide the assessment process (P3M3, 2013) as shown in Table 11.3.

Maturity level	Portfolio	Programme	Project
Level 1: Awareness	Does the company recognise programmes/ projects, and maintain an informal list of its investments in programmes and projects?	Does the company recognise programmes and run them differently from projects?	Does the company recognise projects and run them differently from its ongoing business?
Level 2: Repeatable	Does the company ensure that each programme and/or project in its portfolio is run with its own processes and procedures to a minimum specified standard?	Does the company ensure that each programme is run with its own processes and procedures to a minimum specified standard?	Does the company ensure that each project is run with its own processes and procedures to a minimum specified standard?
Level 3: Defined	Does the company own a centrally controlled programme and project processes? Does the company have its own portfolio management process?	Does the company have its own centrally controlled programme processes and can individual programmes flex within these processes to suit the particular programme?	Does the company have its own centrally controlled project processes and can individual projects flex within these processes to suit the particular project?
Level 4: Managed	Does the company obtain and retain specific management metrics on its whole portfolio of programmes and projects?	Does the company obtain and retain specific measurements on its programme management performance?	Does the company obtain and retain specific measurements on its project management performance?
Level 5: Optimised	Does the company undertake continuous process improvement for the portfolio?	Does the company undertake continuous process improvement for programmes?	Does the company undertake continuous process improvement for projects?

Table 11.3 P3M3 maturity levels (P3M3, 2013).

Guangshe et al. (2008) have done a comparison across four project maturity models (CCM, PMMM, OPM3, P3M3) by examining their features, primary focus and nature of assessment. Their results are briefly summarised in Table 11.4.

	CMM	**PMMM**	**P3M3**	**OPM3**
Features	Stage model, no existing relationship between different maturity levels.	Stage model, lower maturity levels must be met before moving to higher maturity levels.	Stage model which does not indicate an improvement path.	A continuous model which has a clear roadmap on how to move from lower maturity levels to higher maturity levels.
Primary focus	Software management.	Nine criteria in project management.	Organisational culture, project management and knowledge management.	Cultural, technological and human resources.
Nature of assessment	Based on software evaluation.	Based on software evaluation.	Handbook and guidelines provided to the public.	Assessment done in a closed circulation.

Table 11.4 Comparison across four project maturity models (Guangshe et al., 2008; Khoshgoftar and Osman, 2009).

Project maturity and performance

Empirical evidence appears to show that there is a link between project management formalisation, that is, specification of practices in the form of maturity levels (Milosevic and Patanakul, 2005) and adoption of higher maturity levels with project performance (Dooley et al., 2001; Yazici, 2009; Lu et al., 2008). For example, Jiang et al. (2004) conduct a survey among software engineers based on CMM to identify software development difficulties and find that managerial control has a positive impact on project performance measures. Using CMM as well, Dooley et al. (2001) found evidence that higher maturity levels lead to better project results on 39 new product development programs. Yazici (2009) finds that project management maturity is significantly related to business performance, claiming that increased project management maturity together with results-oriented organisational culture lead to organisational competitiveness, cost savings and increased sales. Lu et al. (2008) investigate the relationship between maturity criteria and project performance indices in software development projects using gene analysis, regression analysis and correlation analysis. They conclude that there is a close connection between project performance indices and different maturity criteria such as finding out the reasons behind mistakes in software development; ability to contrast and evaluate inferior technology; and software engineer's attitude to rights and responsibilities among others. Hellered (2010) focuses on the value of having an established project management model across two companies. The findings from the study demonstrate that although companies with low maturity can still deliver successful projects, there are still advantages of adopting higher project management maturity levels such as 'increased profitability, facilitated monitoring of each project's progress and less dependency on individuals' (Hellered, 2010, p. 1).

11.3 Measuring PSML

A list of criteria to assess PSML is proposed – integration, scope, cost, human resource management, communication and procurement (see Appendix T for details). Under each of these main criteria are subcriteria. For each subcriterion, four levels of maturity are presented, namely ad hoc, defined, managed and integrated (similar to Chapter 10).

11.3.1 Fuzzy-based approach

Fuzzy-based approaches have been widely used in the field of project management (Xu et al., 2010; Chan et al., 2009; Singh and Tiong, 2005). Zadeh (1965, p. 339) was first to introduce the concept of fuzzy sets, defined as a class of objects with a continuum of 'grades of membership'. This means that a fuzzy set A in X (where X is a collection of objects denoted by *x*) is given by a membership function $f_a(x)$ which represents the 'grade of membership' of *x* in A. The nearer the value is to unity (given by 1), the higher the grade of membership. As an example, if three members in fuzzy set A, namely x_1, x_2, x_3 have membership values as 0.2, 0.5 and 0.8, the fuzzy set A can be written as A = {(x_1,0.2), (x_2 ,0.5), (x_3,0.8)} where member x_3 which has the closest value to 1 is assumed to have the highest grade in fuzzy set A. While there are many different functions for characterising fuzzy numbers, for example, linear, non-linear and exponential functions (Tan et al., 2011), linear functions (such as the triangular fuzzy membership function) are perceived to be simple and are able to serve their purpose well. Three relevant definitions pertaining to triangular fuzzy membership are discussed here:

Definition 1:

A triangular fuzzy number with member x, denoted x (a_1, a_2, a_3), has the following membership function (Li et al., 2007):

$$\upsilon = \begin{cases} 0, & x < a_1 \\ (x - a_1)/(a_2 - a_1) & a_1 \le x \le a_2 \\ (a_3 - x)/(a_3 - a_2) & a_2 \le x \le a_3 \\ 0, & x > a_3 \end{cases} \tag{11.1}$$

where a_1, a_2 and a_3 denote lower limit value, mean value and upper limit value.

Definition 2:

If there are two fuzzy numbers A and B parameterised by the triplet (a_1, a_2, a_3) and (b_1, b_2, b_3), then the operations of triangular fuzzy number can be expressed as (Tan et al., 2011; Chang, 1996):

$$\text{(i)} A(+)B = (a_1, a_2, a_3) + (b_1, b_2, b_3) = (a_1 + b_1, a_2 + b_2, a_3 + b_3) \tag{11.2}$$

$$\text{(ii)} A(-)B = (a_1, a_2, a_3) - (b_1, b_2, b_3) = (a_1 - b_1, a_2 - b_2, a_3 - b_3) \tag{11.3}$$

$$\text{(iii)} A(x)C = (a_1, a_2, a_3) x (b_1, b_2, b_3) = (a_1 b_1, a_2 b_2, a_3 b_3) \tag{11.4}$$

Definition 3:

Distance between triangular fuzzy numbers A (a_1, a_2, a_3) and B (b_1, b_2, b_3) can be computed based on a classical geometrical interpretation given by Equation (11.5):

$$D(A,B)=\begin{cases}\left(\dfrac{1}{3}\displaystyle\sum_{i=1}^{3}|a_i-b_i|^p\right)^{1/p}, 1\le p\le\infty\\ \max(|a_i-b_i|), p=\infty\end{cases} \tag{11.5}$$

If p = 2, it is reduced to a Euclidean distance measurement. This is most commonly used for distance measurement in triangular fuzzy numbers. For example, if A and B are two real numbers where $a_1 = a_2 = a_3 = a$ and $b_1 = b_2 = b_3 = b$, the distance between them is similar to a Euclidean distance calculation (Tan et al., 2011).

$$D(A,B)=\sqrt{\frac{1}{3}\left[(a_1-b_1)^2+(a_2-b_2)^2+(a_3-b_3)^2\right]}=\sqrt{\frac{1}{3}\left[(a-b)^2+(a-b)^2+(a-b)^2\right]}=\sqrt{(a-b)^2}$$

$$=|a-b|$$

11.3.2 Linguistic terms

Assessing project sustainability maturity level (PSML) is not a clear-cut process and involves a high degree of uncertainty. Hence, in reality it is not practical to use just a single deterministic value as a representation of a project's maturity level. Rather, project assessors may find the use of linguistic terms easier to express their opinion with. Likewise, weightings which reflect on the importance of subcriteria can be expressed with linguistic expressions such as 'very important', 'important', 'moderately important', 'less important' or 'least important'. Tan et al. (2011) suggest that the use of such linguistic expressions can be associated with fuzzy set membership.

Since four levels are already defined for measuring project sustainability maturity, namely ad hoc, defined, managed and integrated (see Appendix T), this can be used as an appropriate set of linguistic terms. The set up of appropriate linguistic terms (for maturity level rating and weighting) and corresponding fuzzy set numbers are shown in Tables 11.5a and 11.5b.

It is recommended that PSML be assessed by a group of professional members according to their knowledge and experience. A total of 15 subcriteria across the aforementioned project management areas are proposed to assess sustainability maturity (see Appendix T). The panel will be involved in selecting appropriate linguistic terms which best describes the maturity level for all subcriteria and their respective weightings.

Maturity level rating	Triangular fuzzy numbers
Ad hoc (AH)	(0,0,0.1)
Defined (D)	(0.1,0.3,0.5)
Managed (M)	(0.5,0.7,0.9)
Integrated (I)	(0.9,1.0,1.0)

Table 11.5a Maturity level rating and corresponding triangular fuzzy numbers.

Weighting	Triangular fuzzy numbers
Very low (VL)	(0,0,0.1)
Low (L)	(0,0.1,0.3)
Fairly low (FL)	(0.1,0.3,0.5)
Fair (F)	(0.3,0.5,0.7)
Fairly high (FH)	(0.5,0.7,0.9)
High (H)	(0.7,0.9,1.0)
Very high (VH)	(0.9,1.0,1.0)

Table 11.5b Weighting and corresponding triangular fuzzy numbers.

As there are usually more than one panel member involved in the assessment process, average fuzzy ratings and average fuzzy weightings for subcriteria are used as a representation of their opinions. For subcriterion k, the average fuzzy rating is given as:

$$\tilde{S}_k = \frac{1}{n}\sum_{i=1}^{n}\tilde{s}_i \qquad (11.6)$$

While the average fuzzy weighting is given as:

$$\tilde{W}_k = \frac{1}{n}\sum_{i=1}^{n}\tilde{w}_i \qquad (11.7)$$

where i = 1, 2, ... , n denotes the number of panel members.

A PSML rating introduced in Equation (11.8) consolidates the average fuzzy ratings and fuzzy weightings of subcriteria (under each main criterion) to represent the sustainability maturity level of a criterion.

$$\text{PSML rating} = \sum_{k=1}^{t}\tilde{W}_k \text{ x } \tilde{S}_k \qquad (11.8)$$

The PSML rating is a triangular fuzzy number. To maintain the value of the PSML rating within the [0, 1] range, normalisation is required. A simple way to do this is to divide the PSML rating with the maximum upper limit value (a*). a* can be obtained by setting all fuzzy ratings of subcriteria as the maximum rating (0.9,1,1) and maintaining the weightings (see PSML' in section 11.4).

If the PSML rating = (P_1, P_2, P_3) and a* is the maximum upper limit value, the normalised PSML rating (NPSML rating) is calculated using the following equation:

$$\text{NPSML rating} = \left(\frac{P_1}{a^*}, \frac{P_2}{a^*}, \frac{P_3}{a^*}\right) \qquad (11.9)$$

NPSML rating can be mapped to an appropriate linguistic term. This is called a natural language expression set. Following a few authors (see Lin and Chen, 2004; Li et al., 2007; Tan et al., 2011), this chapter adopts a natural language expression set as shown in Table 11.6.

Natural language expression set	Fuzzy numbers
Extremely low maturity (EL)	(0,0.1,0.2)
Very low maturity (VL)	(0.1,0.2,0.3)
Low maturity (L)	(0.2,0.3,0.4)
Fairly low maturity (FL)	(0.3,0.4,0.5)
Fair maturity (F)	(0.4,0.5,0.6)
Fairly high maturity (FH)	(0.5,0.6,0.7)
High maturity (H)	(0.6,0.7,0.8)
Very high maturity (VH)	(0.7,0.8,0.9)
Extremely high maturity (EH)	(0.8,0.9,1.0)

Table 11.6 Natural language expression set.

While there are a few different techniques for mapping the NPSML rating to a linguistic term from a natural language expression set, perhaps the distance form given in Equation (11.5) is the most intuitive as it captures the 'subjective perception of proximity' (Tan et al., 2011, p. 239). That is to say, the distance between NPSML rating and each member of the natural language expression set from Table 11.6 can be calculated and the maturity level of a criterion can be determined by using the linguistic term from the natural language expression set giving the smallest distance.

11.4 Example

Consider a project management team wishing to conduct a PSML assessment on a construction-based project using the fuzzy-based approach. The steps involved are detailed as follows:

Step 1: Setting up panel

Three experienced panel members are selected to provide their assessment of the sustainability maturity level for the subcriteria proposed in Appendix T.

Step 2: Provide weightings and ratings

Based on available data or evidence, each of the panel members will express the importance of each of the subcriteria by specifying weightings. Ratings will be given to each subcriterion to measure their maturity level. These (weightings and ratings) can be expressed using the linguistic terms proposed in Tables 11.5a and 11.5b. An example of panel members' opinions are captured in Tables 11.7a and 11.7b respectively, with the latter being the transformed triangular fuzzy numbers.

Criterion/Subcriterion	**Panel 1**		**Panel 2**		**Panel 3**	
	$\tilde{w}_1$	$\tilde{s}_1$	$\tilde{w}_2$	$\tilde{s}_2$	$\tilde{w}_3$	$\tilde{s}_3$
Integration						
Project planning	FH	AH	FH	M	FH	I
Project execution	FH	M	FH	M	FH	M
Change control	H	M	H	M	H	I
Information handling	H	M	H	M	H	M
Scope						
Business requirements	FH	AH	FH	M	FH	I
Technical requirements	F	AH	H	M	H	I
Deliverables	FH	D	FH	D	FH	I
Scope change	F	D	H	D	H	I
Cost						
Project estimation	F	D	F	M	F	I
Human Resource Management						
Resource planning	H	AH	H	M	H	M
Recruitment process	H	D	H	D	H	I
Communication						
Planning	H	AH	H	M	H	I
Sustainability reporting	H	AH	H	M	H	I
Procurement						
Planning	F	M	F	M	F	I
Contract management	F	D	F	M	F	I

Table 11.7a Panel members' judgement on weightings and ratings.

Criterion/ Subcriterion	Panel 1		Panel 2		Panel 3	
	$\tilde{w}_1$	$\tilde{s}_1$	$\tilde{w}_2$	$\tilde{s}_2$	$\tilde{w}_3$	$\tilde{s}_3$
Integration						
Project planning	(0.5,0.7,0.9)	(0,0,0.1)	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.9,1.0,1.0)
Project execution	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.5,0.7,0.9)
Change control	(0.7,0.9,1.0)	(0.5,0.7,0.9)	(0.7,0.9,1.0)	(0.5,0.7,0.9)	(0.7,0.9,1.0)	(0.9,1.0,1.0)
Information handling	(0.7,0.9,1.0)	(0.5,0.7,0.9)	(0.7,0.9,1.0)	(0.5,0.7,0.9)	(0.7,0.9,1.0)	(0.5,0.7,0.9)
Scope						
Business requirements	(0.5,0.7,0.9)	(0,0,0.1)	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.9,1.0,1.0)
Technical requirements	(0.4,0.5,0.6)	(0,0,0.1)	(0.7,0.9,1.0)	(0.5,0.7,0.9)	(0.7,0.9,1.0)	(0.9,1.0,1.0)
Deliverables	(0.5,0.7,0.9)	(0.1,0.3,0.5)	(0.5,0.7,0.9)	(0.1,0.3,0.5)	(0.5,0.7,0.9)	(0.9,1.0,1.0)
Scope change	(0.4,0.5,0.6)	(0.1,0.3,0.5)	(0.7,0.9,1.0)	(0.1,0.3,0.5)	(0.7,0.9,1.0)	(0.9,1.0,1.0)
Cost						
Project estimation	(0.3,0.5,0.7)	(0.1,0.3,0.5)	(0.3,0.5,0.7)	(0.5,0.7,0.9)	(0.3,0.5,0.7)	(0.9,1.0,1.0)
Human Resource Management						
Resource planning	(0.7,0.9,1.0)	(0,0,0.1)	(0.7,0.9,1.0)	(0.5,0.7,0.9)	(0.7,0.9,1.0)	(0.9,1.0,1.0)
Recruitment process	(0.7,0.9,1.0)	(0.1,0.3,0.5)	(0.7,0.9,1.0)	(0.1,0.3,0.5)	(0.7,0.9,1.0)	(0.9,1.0,1.0)
Communication						
Planning	(0.7,0.9,1.0)	(0,0,0.1)	(0.7,0.9,1.0)	(0.5,0.7,0.9)	(0.7,0.9,1.0)	(0.9,1.0,1.0)
Sustainability reporting	(0.7,0.9,1.0)	(0,0,0.1)	(0.7,0.9,1.0)	(0.5,0.7,0.9)	(0.7,0.9,1.0)	(0.9,1.0,1.0)
Procurement						
Planning	(0.3,0.5,0.7)	(0.5,0.7,0.9)	(0.3,0.5,0.7)	(0.5,0.7,0.9)	(0.3,0.5,0.7)	(0.9,1.0,1.0)
Contract management	(0.3,0.5,0.7)	(0.1,0.3,0.5)	(0.3,0.5,0.7)	(0.5,0.7,0.9)	(0.3,0.5,0.7)	(0.9,1.0,1.0)

Table 11.7b Mapping of panel members’ judgement to triangular fuzzy numbers.

Step 3: Combining panel members' opinions

Using Equations (11.6) and (11.7), panel members' opinions can be aggregated. The average fuzzy weightings and ratings are as shown in Table 11.8.

Criterion/Subcriterion	Average fuzzy weightings	Average fuzzy ratings
Integration		
Project planning	(0.5,0.7,0.9)	(0.47, 0.57,0.67)
Project Execution	(0.5,0.7,0.9)	(0.5,0.7,0.9)
Change control	(0.7,0.9,1.0)	(0.63,0.8,0.93)
Information handling	(0.7,0.9,1.0)	(0.5,0.7,0.9)
Scope		
Business requirements	(0.5,0.7,0.9)	(0.47,0.57,0.67)
Technical requirements	(0.6,0.77,0.87)	(0.47,0.57,0.67)
Deliverables	(0.5,0.7,0.9)	(0.37,0.53,0.67)
Scope change	(0.6,0.77,0.87)	(0.37,0.53,0.67)
Cost		
Project estimation	(0.3,0.5,0.7)	(0.5,0.67,0.8)
Human resource management		
Resource planning	(0.7,0.9,1.0)	(0.47,0.57,0.67)
Recruitment process	(0.7,0.9,1.0)	(0.37,0.53,0.67)
Communication		
Planning	(0.7,0.9,1.0)	(0.47,0.57,0.67)
Sustainability reporting	(0.7,0.9,1.0)	(0.47,0.57,0.67)
Procurement		
Planning	(0.3,0.5,0.7)	(0.63,0.8,0.93)
Contract management	(0.3,0.5,0.7)	(0.5,0.67,0.8)

Table 11.8 Average fuzzy weightings and ratings.

Step 4: Determining PSML and NPSML ratings

By applying equations (11.8) and (11.9), PSML and NPSML ratings can be determined. The results are shown in Table 11.9.

For the human resource management criterion, the calculation process is demonstrated as follows:

$$\begin{aligned}\text{PSML rating} &= (0.7,0.9,1.0)\text{x}(0.47,0.57,0.67) + (0.7,0.9,1.0)\text{x}(0.37,0.53,0.67)\\ &= (0.59,0.99,1.34)\end{aligned}$$

$$\text{PSML}' = (0.7,0.9,1.0)\text{x}(0.9,1.0,1.0) + (0.7,0.9,1.0)\text{x}(0.9,1.0,1.0)$$

$$= (1.26,1.8,2)$$

Hence, a* = 2 for human resource management.

$$\text{NPSML rating} = \left(\frac{0.59}{2},\frac{0.99}{2},\frac{1.34}{2}\right)$$

$$= (0.29,0.5,0.67)$$

Criterion	PSML rating	NPSML rating
Integration	(1.28,2.24,3.24)	(0.34,0.59,0.85)
Scope	(0.92,1.62,2.37)	(0.26,0.46,0.67)
Cost	(0.15,0.34,0.56)	(0.21,0.48,0.8)
Human resource management	(0.59,0.99,1.34)	(0.29,0.5,0.67)
Communication	(0.66,1.03,1.34)	(0.33,0.51,0.67)
Procurement	(0.34,0.74,1.21)	(0.24,0.53,0.87)

Table 11.9 PSML and NPSML ratings.

Step 5: Mapping NPSML rating to suitable linguistic terms

From the results in Step 4 (see Table 11.9), each calculated NPSML rating can be mapped to a linguistic term in the natural language expression set to represent the level of sustainability maturity. Based on Equation (11.5), the distance between NPSML rating and each member in the natural language expression set (see Table 11.6) is shown in Table 11.10. The maturity level is determined based on the smallest distance of a linguistic term to the NPSML rating. For example, the maturity level for integration is 'Fairly High' given that it has the minimum distance D (Integration, FH) = 0.13.

Criterion	EL	VL	L	FL	F	FH	H	VH	EH
Integration	0.51	0.41	0.32	0.23	0.16	0.13	0.17	0.24	0.33
Scope	0.37	0.28	0.18	0.11	0.09	0.16	0.25	0.35	0.45
Cost	0.43	0.34	0.25	0.19	0.16	0.19	0.26	0.34	0.43
Human resource management	0.39	0.30	0.20	0.11	0.08	0.14	0.23	0.32	0.42
Communication	0.41	0.31	0.21	0.12	0.06	0.11	0.20	0.30	0.40
Procurement	0.48	0.39	0.30	0.23	0.18	0.18	0.23	0.31	0.39

Table 11.10 Distances between NPSML rating and the natural language expression set.

Step 6: Final analysis

Once all the distances between the NPSML rating and the natural language expression set (see Table 11.10) are computed, the maturity levels for all criteria are determined. In this example, it can be observed that integration has a 'Fairly High' maturity level while scope, cost, human resource management and communication have 'Fair' maturity levels. Procurement has either a 'Fair' or 'Fairly High' maturity level. This may warrant further investigation or reassessment to truly identify the sustainability maturity level of procurement practices.

11.5 Conclusion

This chapter recommends a fuzzy-based approach to measure project sustainability maturity levels across criteria such as integration, scope, cost, human resource management, communication and procurement. Understanding strengths and weaknesses is important to help construction practitioners develop effective project management strategies to meet sustainability goals. The PSML and NPSML ratings demonstrated here can also be used by clients to rank and select contractors who would best help the project management team to attain sustainability goals. For future research, it is proposed that the suitability of the linguistic terms be validated with actual case studies. The fuzzy numbers and corresponding linguistic terms may then be altered accordingly.

CHAPTER 12 – INTEGRATING ESG INTO INVESTMENT DECISION MAKING

12.1 Introduction

Typically investment decision making is not based on just selecting an individual asset but rather a combination of assets known as a portfolio. Portfolio selection has been defined as a process of selecting an optimal portfolio which strikes a balance between maximising returns and minimising risk given an uncertain environment (Huang, 2010). This concept is also used in the optimisation of project portfolios (see Walls, 2004; Graves et al., 2000; Orman and Duggan, 1999; Laurikka and Springer, 2003 among others).

Extending the framework for sustainability reporting presented in Chapter 8 and the classification tree model introduced in Chapter 9, a method to integrate ESG into portfolio selection is proposed. In particular, it builds on the existing, widely used concept of the efficient frontier to assist in the financial return and sustainability (or ESG) assessment of portfolios. The proposed approach to portfolio selection is exampled on sample company data from the New York Stock Exchange (NYSE). This approach is also applicable for the selection of Real Estate Investment Trusts (REITs) where sustainability is assessed using building SRTs (see Chapter 3 for details).

The remainder of this chapter is organised as follows. Firstly, the state-of-the-art in modern portfolio theory (MPT) is reviewed. Secondly, essential concepts used in this chapter are presented. The method proposed is exampled on companies selected from two clusters, namely ‘Leader’ and ‘Average’ (see Chapter 9). This is followed by a discussion of some of the key assumptions made.

12.2 Background

Modern portfolio theory (MPT)

Modern portfolio theory (MPT) is a body of financial economics made popular by Markowitz (1952) based on his paper ‘Portfolio Selection’ and extended through time with a variety of names; ‘Financial Decision Making Under Uncertainty’, ‘The Theory of Investments’ and ‘Theory of Asset Selection’ among others (French, 2010).

The literature on MPT deals with the establishment of an optimal investment portfolio by concentrating on risk at least as much as return (Elton and Gruber, 1997; Fama and French, 2004; Bowman, 1979; Cohen et al., 1983; Mandelker and Rhee, 1984; Mohd. Ali, 2006; Mohamed, 2010). Note that risk in this chapter is used in the same sense as Markowitz (1952) with a reference to variation in return unless mentioned otherwise. Asset classes which form part of the portfolio could be stocks, bonds or even real estate investments. The return and risk of portfolios are given as follows (Mohamed, 2010):

$$R_p = \sum_{i=1}^{n} w_i r_i \tag{12.1}$$

$$\sigma^2_p = \sum_{i=1}^{n} w_i^{\,2} \sigma_i^{\,2} + \sum_{i=1}^{n} \sum_{j=1, j\neq i}^{n} w_i w_j \rho_{ij} \sigma_i \sigma_j \tag{12.2}$$

where R_p is the return of the portfolio, σ^2_p is the portfolio variance, σ_i is the standard deviation on asset i, w_i is the weighting of each asset, r_i is the return of an asset, ρ_{ij} refers to the coefficient of correlation between assets i and j. n simply refers to the number of assets in a portfolio (see Markowitz, 1952; Muller, 1988 for more detailed mathematical modelling).

Assuming that all investors are rational, a clear trade-off between risk and return can be expected. One of the most widely discussed concepts of this particular trade-off is known as the capital asset pricing model (CAPM) depicted by the security market line (SML) in Figure 12.1 (see Fama and French, 2004 for details). It determines the expected return on the y-axis given the portfolio’s beta (β). β on the x-axis (see

Bowman, 1979; Cohen et al., 1983; Mandelker and Rhee, 1984) measures the sensitivity of returns for the portfolio moving with some broad-based market index (Mohd. Ali, 2006). Figure 12.1 illustrates a linearly positive trade-off between risk and return. From this figure, there are assets that are considered to have zero risk, represented by R_f (for example, Treasury bills). A higher β indicates a more volatile portfolio; however, if investors are willing to take this risk, they may gain a higher expected return. Portfolio M consists of weighted average of all quoted assets representing the total economy, and investing in this portfolio would mean that an investor can expect to earn a return on the market.

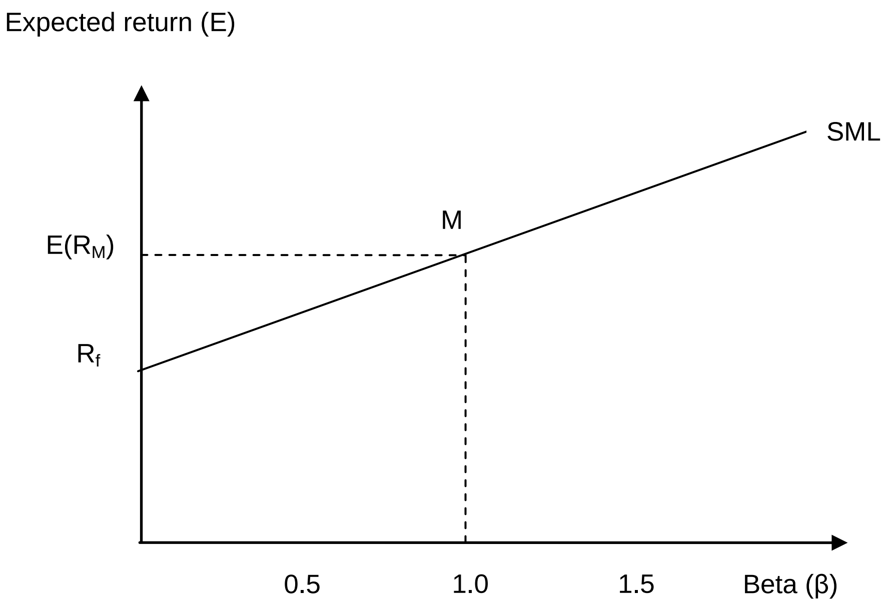


Figure 12.1 Security market line (Mohamed, 2010).

As can be anticipated, a large number of portfolios are always available for investment with different expected returns and risks. And the investor is likely to be confronted with the problem of selecting the optimal portfolio. To solve this problem, the concept on efficient frontiers has been introduced (Muller, 1988; Mohamed, 2010). Portfolio x* is considered efficient when there are no portfolios x with (see Muller, 1988 for details):

$$E[R(x)] \geq E[R(x^*)] \tag{12.3}$$

$$\mathrm{Var}[R(x)] \leq \mathrm{Var}[R(x^*)] \tag{12.4}$$

where E[R(x)] is the expected return of portfolio x and Var[R(x)] is the variance of portfolio x.

There are other extensive contributions in the literature on portfolio analysis. Sharpe (1963) introduces a simplified model for portfolio analysis and finds that relatively few parameters used by the model can lead to similar results obtained with larger data sets. Shalit and Yitzhaki (1984) present the mean-Gini (MG) approach to analyse risky prospects and assist in the construction of optimum portfolios. Shefrin and Statman (2000) develop behavioural portfolio theory (BPT) and explore its implications for portfolio construction and security design. Lo and Wang (2000) discuss the implications of portfolio theory for cross-sectional behaviour of an asset’s trading volume. Onnela et al. (2003) find that the diversification aspect of a classic Markowitz portfolio results in assets that are located on the outer leaves of the ‘asset tree’. Biglova et al. (2004) discuss different approaches used and suitability in estimating risk in portfolio theory.

In terms of application, MPT has been used across a wide range of fields. Orman and Duggan (1999) demonstrate how portfolio-optimisation techniques can be used by exploration and production (E&P) companies to identify a mix of projects which provides the minimum risk for a given level of return. Williams (1996) creatively applies MPT to economic base analysis using employment and wage data. Each metropolitan statistical area (MSA) is assumed to be a single portfolio consisting of different industry sectors and government services. The use of MPT involving real estate is particularly prominent. Brueggeman et al. (1984) assess the potential for diversification benefits by combining real estate, stocks and bonds into a portfolio. Alan and Richard (1991) investigate the hypothesis that greater gains come from mixed-asset portfolios that include foreign financial assets and foreign real estate. Their results show that incorporating foreign real estate does not improve foreign portfolio performance. Webb et al. (1988) demonstrate that for an optimal mixed-asset portfolio, two-thirds of the investment wealth should be allocated to real estate while one-third to the financial markets. Bryen and Lee (1997) suggest using the mean absolute deviation

(MAD) to overcome non-normality in the use of MPT for real estate analysis while Sivitanides (1998) introduces the downside-risk (DR) approach for real estate portfolio structuring.

Several researchers considered uncertainty in portfolio modelling. Dorfleitner and Utz (2012) propose incorporating stochastic returns into safety-first models in portfolio selection. Ballestero et al. (2007) introduce a methodology for portfolio selection accounting for multiple scenarios under uncertainty. Shing and Nagasawa (1999) extend portfolio analysis to examine cases where the mean and variance of the return of securities have several scenarios with known occurrence probabilities. Abdelaziz et al. (2007) suggest the use of multi objective stochastic programming models. There are no portfolio studies that consider uncertainty in both financial and ESG performance which is addressed in this chapter.

12.3 Data and method

The method introduced in this chapter endorses the need to account for variability in ESG. The mean value (E[X]) and variances (Var[X]) of ESG can simply be computed using part of the Program Evaluation and Review Technique (PERT) device given as follows:

$$E[X] = (a + 4b + c)/6 \tag{12.5}$$

where X represents a single performance criterion (ENV, SOC, GOV or ESG), a is the optimistic estimate of the criterion, b is the most likely estimate of the criterion while c is the pessimistic estimate of the criterion.

$$\mathrm{Var}[X] = [(c - a)/6]^2 \tag{12.6}$$

Much of this has been discussed in Chapter 8. Random assets listed on the New York Stock Exchange (NYSE) with at least 15 years of KLD scores (see Chapter 2 for details) are selected to illustrate the method proposed. Optimistic estimates are taken to be representative of the highest scores received, most likely estimates are taken as the 15 year average while pessimistic estimates are the lowest scores in the 15 year time frame. These estimations can be adjusted for depending on the value judgement of portfolio managers or institutional investors. Two random portfolios based on different asset combinations are created as shown in Table 12.1. Group 1 members are selected from the 'Leader' cluster whereas group 2 members are selected from the 'Average' cluster (see Chapter 9).

	Assets	Return	Risk	ESG	Variance
Group 1	PX	0.0512	0.252	0.29	0.09
	BAX	0.0126	0.275	0.79	0.35
	DIS	-0.0486	0.397	0.25	0.35
	NKE	0.0309	0.254	0.9	0.35
	AMD	-0.130	0.719	0.6	1
Group 2	GGG	0.0281	0.235	0.13	0.01
	USB	-0.0818	0.361	0.32	0.02
	TDS	-0.0235	0.474	0.06	0.00
	STJ	-0.0102	0.346	0.01	0.01
	KEY	-0.127	0.414	0.42	0.12

Table 12.1 Random assets selected for groupings.

12.4 Efficient frontier analysis

The concept of the portfolio efficient frontier refers to a set of feasible portfolios that offers the lowest risk for any given return or the highest return at any level of risk. Portfolios that lie on this line are known as efficient portfolios and are optimised by varying the weightings of individual assets within the portfolio universe; see Equations (12.3) and (12.4). Anything below the efficient frontier is considered to be 'suboptimal' or 'inefficient'.

The current selection process requires two stages: (i) selecting the more superior efficient frontier and (ii) selecting the portfolio among the set of efficient assets.

Using the VisualMVO software (Efficient Solutions, 2011), portfolios which lie on the efficient frontier curves are generated for group 1 (see Table 12.1). The portfolios are constructed by applying Equations (12.1) and (12.2). As there are two sets of measures here (ESG and return), two efficient frontier curves are formed. The first efficient frontier curve (ESG-variance) shows the ESG performance level and variance in Figure 12.2 while the second efficient frontier curve (return-risk) depicts the level of risk and return in Figure 12.3. Mohamed et al. (2010) claim that the efficient frontier closest to the north-west point is preferred because it gives the highest level of return with minimal risk.

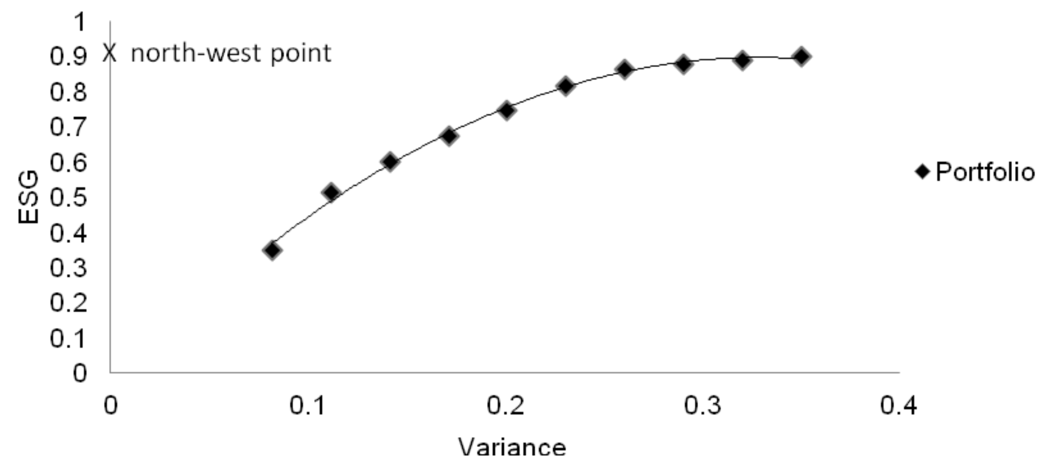


Figure 12.2 ESG–variance efficient frontier analysis.

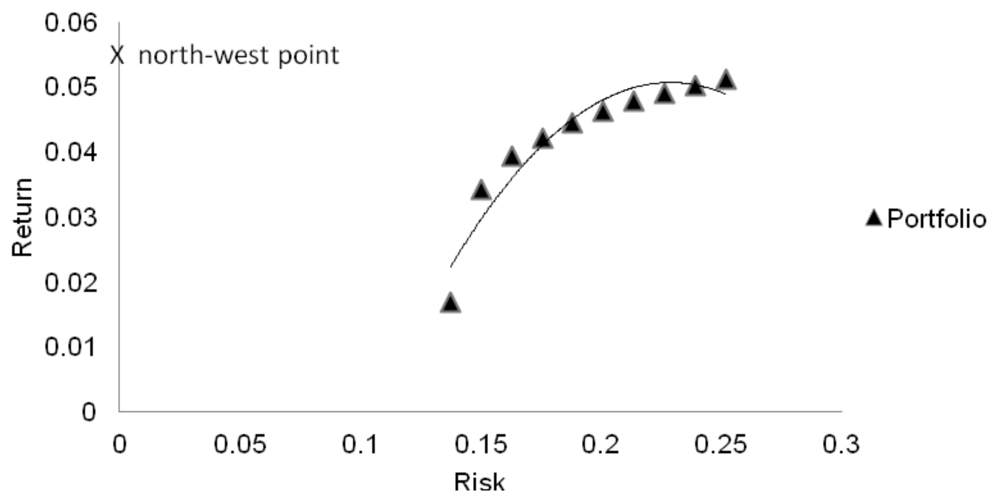


Figure 12.3 Return–risk efficient frontier analysis.

Traditionally, an analyst would have to compare the superiority of all efficient frontier curves before making a decision as to which portfolio is suitable to invest in. To further illustrate this problem, another efficient frontier curve with different asset combinations from group 2 is constructed. This allows for a comparison of efficient frontier curves not just of return-risk but also ESG-variance as shown in Figures 12.4 and 12.5.

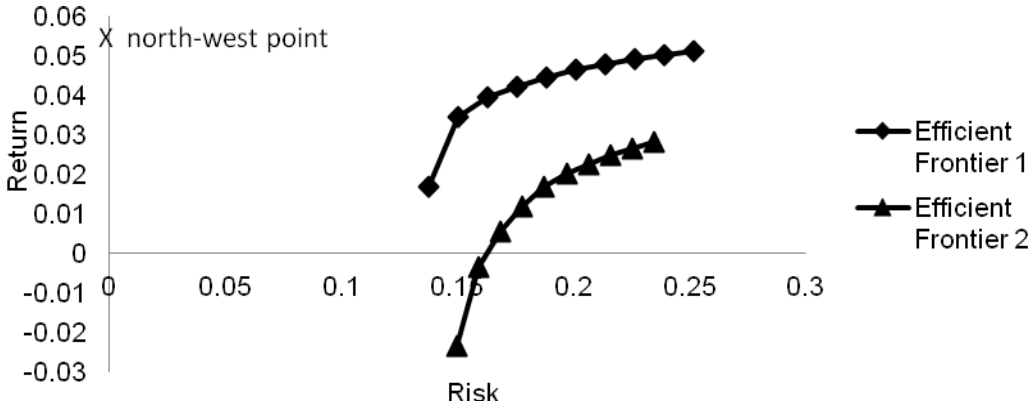


Figure 12.4 Comparison of return–risk efficient frontiers.

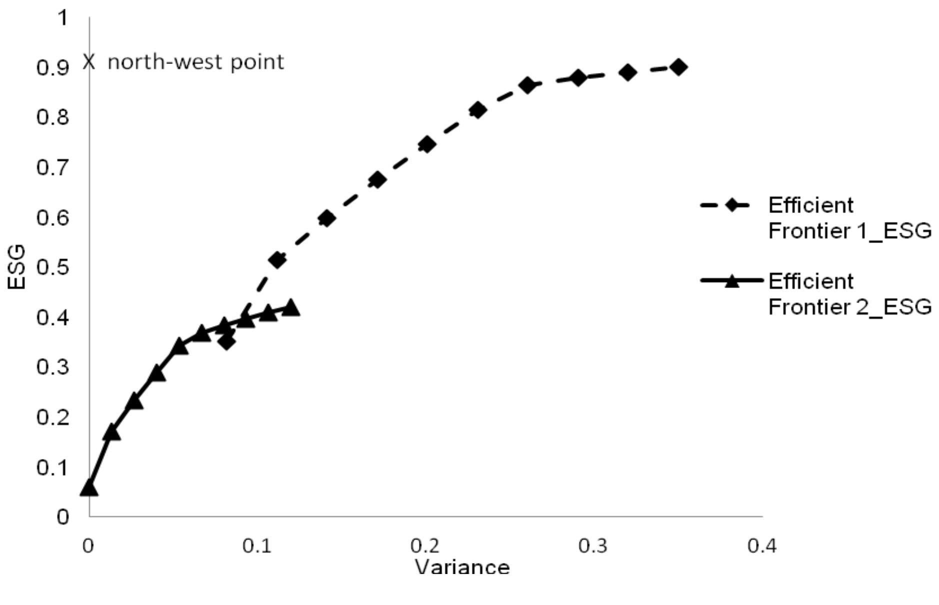


Figure 12.5 Comparison of ESG–variance efficient frontiers.

While the curve with higher efficiency can be inspected visually, there are situations when these curves tend to overlap each other in close proximity and therefore impairing visual judgement. Therefore, the efficient frontier's centre of gravity (COG) which is the 'average' of all points on the respective curves is recommended as a means by which the more superior portfolio could be identified. The more superior portfolio is the one which has the shortest distance to the north-west point. COG can be computed from the following equations:

$$COG_x = \frac{\sum_a^b x_i y_i}{\sum_a^b y_i} \tag{12.7}$$

$$COG_y = \frac{\sum_a^b \frac{1}{2} y_i^2}{\sum_a^b y_i} \tag{12.8}$$

where COG_x is the efficient frontier's risk (for financial returns) or variance (for ESG measures), COG_y is the efficient frontier's return or ESG performance, a and b are the number of feasible portfolios, x_i is the portfolio's value on the x-axis while y_i is the portfolio's value on the y-axis.

To measure the distance of COG from both north-west points: return-risk $(0, C_1)$ and ESG-variance $(0,C_2)$, Euclidean distances as used in distance mapping picture processing (Danielson, 1980; Kolounzakis and Kutulakos, 1992) and shortest path problems in operations research (Golden and Ball, 1978) is recommended. The shorter the distance, the nearer the efficient frontier curves are to the north-west points. And this is the preferred option. Because there are four domains involved (derived from the x and y values from both the return-risk and ESG-variance curves), Euclidean distance is measured by,

$$D(x, y) = \sqrt{(0 - x_1)^2 + (C_1 - y_1)^2 + (0 - x_2)^2 + (C_2 - y_2)^2} \tag{12.9}$$

where D is the Euclidean distance, (x_1, y_1) is the COG coordinate for the return-risk curve while (x_2, y_2) is the COG coordinate for the ESG-variance curve.

To illustrate the concept that has been introduced, a numerical example is shown. The north-west points are (0, 0.0512) for return-risk (Figure 12.4) and (0, 0.9) for ESG-variance (Figure 12.5). Table 12.2 depicts the calculation of the Euclidean distances.

Efficient Frontiers	**Centre of gravity**		**Euclidean Distance**
	COG_x	COG_y	
Efficient Frontier 1 (return-risk)	0.202	0.0222	0.604
Efficient Frontier 1_ESG (ESG-variance)	0.236	0.383	
Efficient Frontier 2 (Return-Risk)	0.222	0.0156	0.763
Efficient Frontier 2_ESG (ESG-Variance)	0.0730	0.175	

Table 12.2 COG and north-west points.

The COG Euclidean distance for Efficient Frontiers 1 and 2 are 0.604 and 0.763 respectively. Because Efficient Frontier 1 (derived from the combination of assets in group 1) has a shorter Euclidean distance, it is preferred. The conventional method is for analysts to consider the efficient frontier curves of return–risk only; this method, however, provides them with an alternative to also consider efficiency from an ESG standpoint, therefore allowing for better integration of ESG into portfolio investment decision making.

Once the combination of assets has been decided through the selection of an efficient frontier, the next stage is to decide on the weightings that should be allocated to each asset. This depends very much on the investor's risk-taking utility and value judgement on ESG. As can be seen from both Figures 12.4 and 12.5, the efficient frontier curves have different weighting allocation for the same asset combination. From these figures, the investor is essentially confronted with a choice of 20 different portfolios to select from (10 from the return–risk curve and another 10 from the ESG–variance curve).

Suppose Efficient Frontier 1 is selected (from Figure 12.4), ESG–variance plots can be determined by applying similar asset weightings as the portfolios constructed in the efficient frontier curve for return–risk. From Figure 12.6, it can be observed how closely apart these new plots are to the ESG efficient solutions. The investor would then make a judgement as to his comfort level in allocating weightings to each asset.

An investor who is more concerned with ESG issues will prioritise assets that are more ESG efficient while a more return-driven investor would give more weighting on assets that generate higher financial returns.

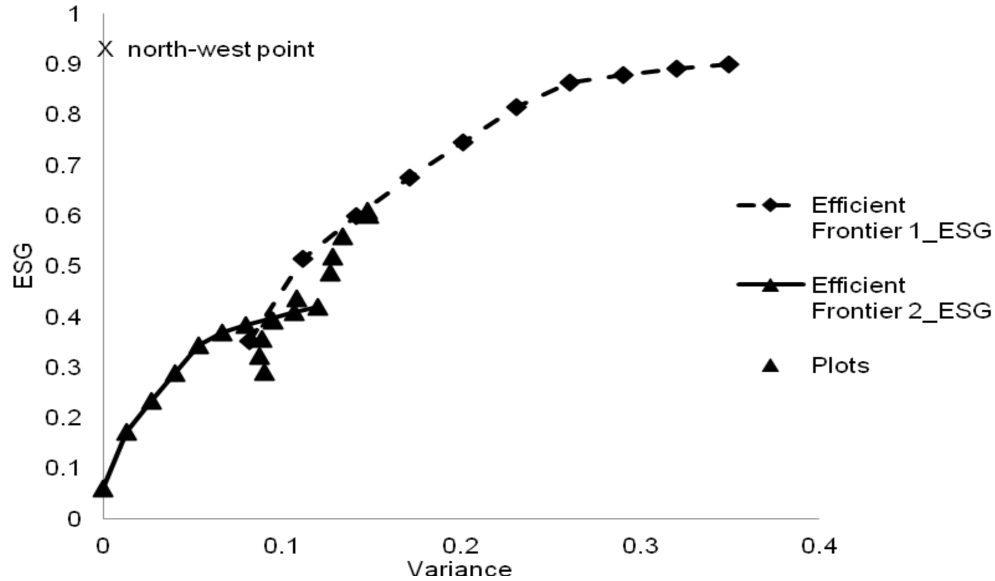


Figure 12.6 Plots on the ESG-variance efficient frontiers.

12.5 Key assumptions of the framework and limitations

There are a few assumptions that are made about investors and the capital markets in the use of modern portfolio theory. Likewise some of the key assumptions and limitations relating to the proposed method are discussed here:

ESG measurement reflective of future financial gains

One of the contentions that critics may have is the notion of redundancy; for example, if ESG is proven to be driving returns and assuming this is already factored into pricing, then perhaps there is no need to have two separate sets of analysis for the efficient frontier curves (return-risk and ESG-variance). In response to this, the chapter argues that segregating the analysis into financial returns and ESG allows investors to more clearly identify, compare and select asset combinations that are most feasible from both a financial and socially responsible standpoint. This helps improve the process of integrating ESG into mainstream investment decision making as ESG now needs to be examined in much greater detail. Current criticism of modern portfolio theory, as well, is that it only considers past performance and that past performance is not necessarily predictive of future gains. The framework now allows for incorporation of both past and future gains (assuming that ESG performance is a predictor of future financial performance).

Efficient market hypothesis

An underlying assumption of MPT is that it relates to the efficient market hypothesis (EMH). According to EMH, it is not possible to consistently achieve returns in excess of average market returns on a risk-adjusted basis. Three major versions of the EMH hypotheses are ‘weak’, ‘semi-strong’ and ‘strong’. Weak EMH states that prices of traded assets already reflected all past publicly-available information. Semi-strong EMH asserts that prices reflect all publicly-available information and change in prices are due to new public information. Strong EMH opines that prices reflect even ‘insider’ information (Omisore et al., 2012). However, there have been arguments made against EMH (see Borges, 2010; Romero-Meza and Gutierrez, 2009; Sewell, 2012 – among others).

Asset returns and ESG performance are normally distributed

For the analysis, it is assumed that both asset returns and ESG performance follow a normal distribution. This assumption, however, has been contested. It has been argued that 3 to 6 standard deviations from the mean tend to occur in the market far more frequently than normal distributions (Omisore et al., 2012).

Investors are rational, risk-averse and socially responsible

It is assumed that investors are rational, risk-averse and socially responsible (believes in maximising ESG performance). Given that there are gamblers who are risk-takers and considering that different investors have different value judgement (perception on ESG), this assumption may not necessarily hold true.

There are no taxes or transaction costs

Real financial products are exposed to taxes and transaction costs such as brokerage fees, and accounting for these may alter the composition of the optimum portfolio.

Trade-off

Another possible contention is the ESG performance trade-off. That is to say, in selecting assets for a portfolio, a company with very low ESG performance may appear among other companies with good ESG performance and the overall portfolio will still look good from an ESG standpoint. If such a concern exists, at the discretion of the investor, this can be dealt with by utilising the classification tree model developed in Chapter 9. For example, an investor may only wish to select companies that belong to the 'Leader' cluster. This guarantees a minimum standard of ESG performance among the pool of companies selected. On another note, such trade-offs are no stranger to the carbon markets. Heavy polluters can achieve carbon neutrality simply by purchasing carbon emission reductions (CERs), also more commonly known as carbon credits.

12.6 Conclusion

The chapter introduces an alternative framework for integrating ESG into portfolio selection. This framework extends the use of efficient frontiers to determine portfolios that are not just efficient from a financial sense but also from an ESG standpoint. Both COG and Euclidean distances are used to then determine the distance to the north-west point; the shortest distance is ascertained as the more superior portfolio. Comparisons are made via the construction of two portfolios consisting of different asset combinations.

Several key assumptions are made in the framework; for example, the predictive ability of both financial and ESG past data as discussed in the chapter. Future research may wish to empirically examine how accurate ESG assessments are and whether they are indeed normally distributed. As well, there are opportunities to further extend this study to investigate the risk-taking utility of investors. The current method as far as the literature is concerned assesses investor's utility based purely on a financial sense.

There is definitely room for a dual-classification integrating investor perception on both financial returns and ESG performance.

CHAPTER 13 – CONCLUSIONS AND FUTURE DIRECTIONS

13.1 Overview

The emphasis on sustainability as a global socio-political issue has seen the proliferation of SRTs for both companies and building/infrastructure projects. Yet, very few studies have examined their usefulness. The speculative benefits of SRTs appear to far outweigh rigorous academic studies which motivates the need for more empirical-based research in this area. The effectiveness of SRTs must be investigated as many stakeholders rely on them in their decision making processes. Any deficiencies may possibly represent a measurement error that could mislead stakeholders. On this note, the first research question (RQ1) is aimed at evaluating the impact of SRTs to justify their usefulness in the set up of a 'green' economy where investing, distributing and purchasing of sustainable-style products (sustainable equities and indices, sustainable mutual funds, sustainable buildings or real estate) is common.

Traditionally, SRTs adopt a deterministic approach for quantifying sustainability performance. However, no longer is this assumption valid as Baumgärtner and Quaas (2009, p. 2009) reason that the sustainability concept is related to the future and good planning for strong sustainability should be 'operationalised for conditions of uncertainty'. Alsulami and Mohamed (2010) consider this as another area lacking adequate research, arguing that sustainability performance assessment so far has not taken into account conditions of uncertainty and hence current assessments might not give correct results to be utilised by decision makers in achieving optimal decisions. As well, there is an increasing call for better and more rigorous methods to measure and integrate sustainability into investment decision making. This is triggered by criticisms surrounding SRTs as highlighted in Chapters 2 and 3. Therefore, the second research question (RQ2) is aimed at further enhancing the impact of current SRTs. This is achieved by proposing an alternative framework for sustainability reporting which advocates the use of the second order moment concept, introducing a tree form classification model of companies' sustainability performance and recommending criteria to capture the sustainability maturity of companies and projects. Other analytical tools are also introduced to help integrate sustainability into investment decision making. Figure 13.1 shows the flow of the research and the summarised findings/proposals from this thesis.

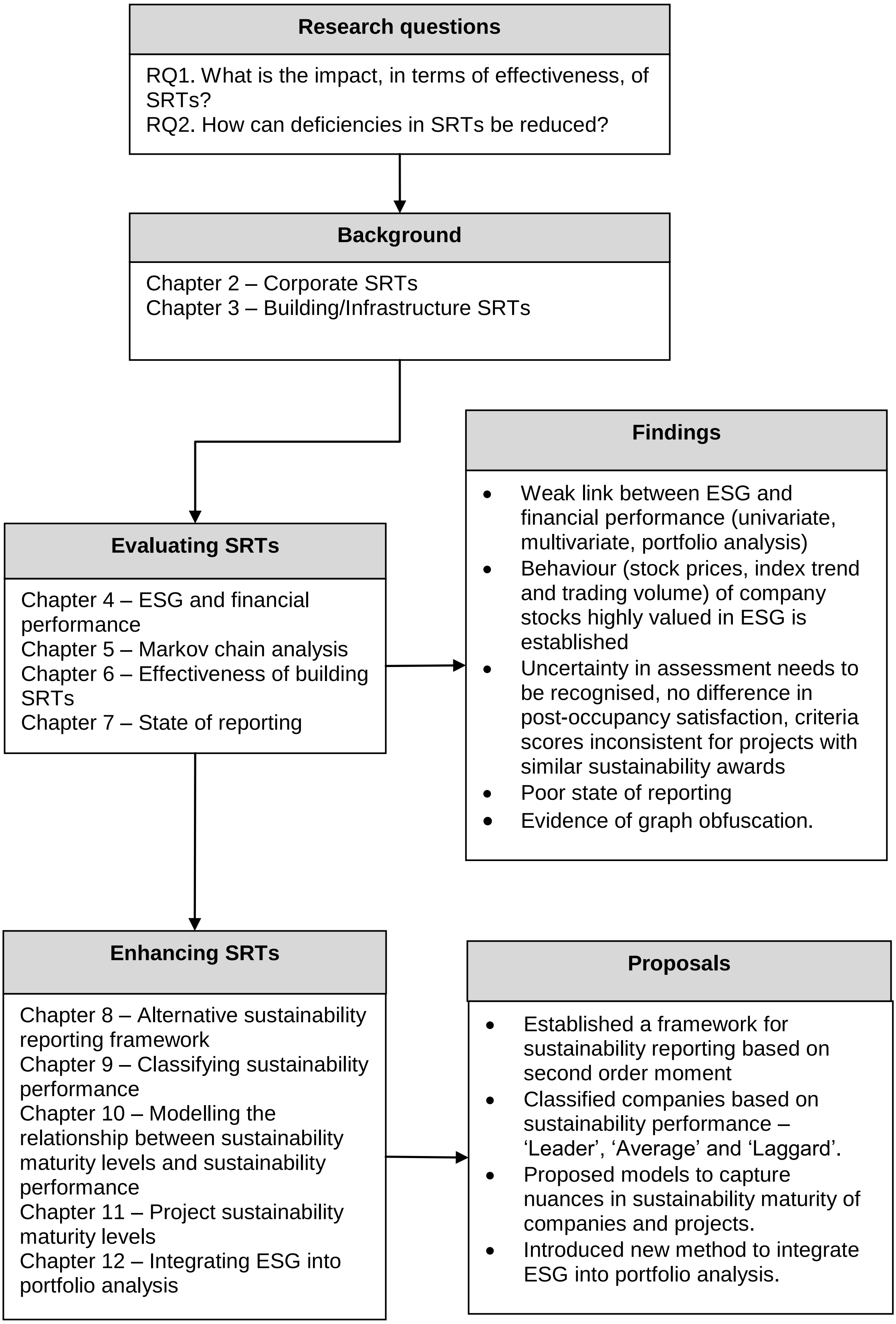


Figure 13.1 Flowchart of the thesis.

13.2 Evaluating the impact of SRTs

The rapid growth of SRTs, with different criteria and methodology, has created complications for stakeholders. The first two chapters provide a review of existing SRTs for companies (see Chapter 2) and buildings/infrastructure (Chapter 3). As presented in Chapter 2, corporate SRTs span across a wide spectrum (frameworks, standards, scores and indices) to help governments, practitioners and individual investors make informed choices. Building SRTs, on the other hand, are largely environmentally focussed. Both Chapters 2 and 3 provide a background on the nature and characteristics of mainstream SRTs. The subsequent four chapters consider the impact of SRTs. In particular, Chapter 4 examines if there is a strong positive relationship between ESG scores (obtained from EIRIS) and financial performance using univariate, multivariate and portfolio analysis. Financial performance is represented by 12 financial ratios (5 profitability ratios and 7 equity valuation) and analysts' forecast error. Contrary to expectation, a weak relationship is found between ESG and financial performance. Results from the portfolio analysis show that ESG laggards outperform ESG leaders. Although analysts' forecast error is negatively correlated to ESG, this observation is insignificant. This study is conducted controlling for both country and industry sector effects.

In Chapter 5, the behaviour (price movement, index trend and trading volume) of the FTSE4Good Australia Index and its constituents is examined using Markov chains. The results show that company stocks that are part of the FTSE4Good Australia Index do not necessarily have superior performance. The impact of SRTs (in the form of ESG scores and indices) in the capital markets is hence questionable.

Chapter 6 investigates the effectiveness of building SRTs via a three-part study. The main findings from the study are: variation in criteria scores and weights need to be accounted for in SRTs; there is no large difference in occupants' satisfaction levels between a sustainable building (ascertained by building SRTs) and a non-sustainable building; and criteria scores are found to be inconsistent for projects with similar sustainability awards. These results might possibly confirm the deficiencies in building SRTs which could potentially lead property investors to base their decisions on flawed information. Extra care would be needed in interpreting the outcomes of building SRTs.

Chapter 7 uses Euclidean distance to examine the state of sustainability reporting of publicly-listed Australian construction companies on climate change, environmental management, environmental efficiency, health and safety, human capital, conduct, stakeholder engagement, governance and other matters deemed to be of concern to institutional investors. As anticipated, results from this study show that a majority of the publicly-listed construction companies studied have low levels of reporting. In addition, by using the relative graph discrepancy (RGD) index, evidence of graph obfuscation is found. The findings here have important policy implication, especially because there is currently no specific regulation concerning graph usage. It would be helpful if advocate organisations such as GRI could prepare guidelines not just on what should be reported but also more explicitly comment on how information should be presented as this could possibly have an influence on stakeholders' decision making process.

In summary, the development of SRTs (both corporate and buildings/infrastructure) although well-intentioned, has possibly grown to a stage where they work counterproductively to their original intent. Instead of bringing structure, standardisation, comparability and quality in sustainability reporting, they are now breeding confusion, inconsistency, contradiction and a lack of credibility based on the findings of this research. In a more direct way, the impact of SRTs may not be as prominent.

13.3 Enhancing the impact of SRTs

To address the need to account for uncertainty in sustainability assessments, Chapter 8 presents a framework based on second order moment thinking. The six elements in the framework are: (i) Criteria selection; (ii) Quantitative measurement scales for the criteria; (iii) Characterising each criterion by measures of central tendency and dispersion; (iv) The distinction of additionality; (v) Criteria weighting; and (vi) Combining criteria to give an overall sustainability score characterised by a measure of central tendency and a measure of dispersion.

Chapter 9 makes an ontological contribution by introducing a classification tree model of companies based on KLD's data. This is useful as it is a first step towards standardising terminology in this research area. Both agglomerative hierarchical clustering as well as classification and regression tree (CART) techniques are used to develop this model. Given that other ESG scoring tools exist such as EIRIS, SAM and ASR, each with its own scoring scale, a more generic regression tree model is also proposed using three normalised criteria, namely *ESG* – a measure of sustainability performance, *STD* – a measure of performance consistency, and *GRAD* – a measure of data trend. By using samples from the NYSE, it is shown that the model is promising and can act as a reliable tool for distinguishing companies' ESG performance. Practitioners are now able to use both of these models to complement their current analysis on sustainability performance.

Because most SRTs fail to capture nuances in sustainability practices of companies, Chapter 10 proposes an original model for measuring sustainability maturity levels. Inputs from the sustainability maturity assessment are then fed into a BBN analysis to examine the relationship between different maturity levels and financial performance. The findings here suggest that when both SR and IP are towards the higher or lower ends of sustainability maturity levels (ad hoc and integrated), there is a larger negative effect on financial performance compared to average sustainability maturity levels (defined or managed).

Chapter 11 shifts the focus towards measuring PSML. While the project management literature has discussed the concept of maturity levels at length, the incorporation of sustainability into project management maturity tools is still very limited. This chapter makes a genuine contribution by (i) suggesting a set of sustainability criteria encompassing various project management areas (integration; scope; cost; human resource management; communication; procurement) and (ii) presenting a fuzzy-based approach to assess PSML.

Based on the framework in Chapter 8 and the classification tree model in Chapter 9, an original method to integrate ESG into traditional portfolio analysis applicable to both companies and buildings is proposed. This method covered in Chapter 12 leverages on several other concepts such as the centre of gravity (COG) and Euclidean distances to help differentiate the superiority of portfolios by accounting for both return–risk and ESG–variance.

13.4 Limitations

This thesis has examined the impact of both corporate and building/infrastructure SRTs in Chapters 4 to 7. Despite the robust research designs, the findings from these studies need to be interpreted with caution. To keep the studies within manageable proportions for a rigorous investigation, the research includes only country-specific data. However, other exogeneous factors such as the effects of different country legislations and policies, which have not been discussed in this thesis, could potentially affect the conclusions drawn. Not all country-specific data were used in this thesis in order to maintain parsimony. As well, some of the research designs (specifically in Chapter 7) may have been limited by the sample size. All of these factors need to be acknowledged in any attempt at generalising the findings. Future work may wish to consider using larger sample sizes of data and extend the analysis to also include other country-specific data outlined in Chapters 2 and 3 respectively.

13.5 Future directions

This thesis has presented results and useful methods to further enhance both corporate and building/infrastructure SRTs culminating in 2 published journal papers and 5 conference papers. This research is timely given the proposal to create a new connected and integrated reporting model following The Prince's Accounting for Sustainability Forum (A4S) which convened in 2009. The establishment of the international reporting framework is expected to not only 'integrate both financial and sustainability outcomes but also support the achievement of a sustainable economy' (Fries et al., 2010, pp. 44–45). The findings and proposals made in this thesis may serve as an important input to the process. As well, researchers and stakeholders may be interested in these findings to better understand current issues of importance for sustainability reporting across companies and building/infrastructure projects. SRT developers in other disciplines who are keen on investigating the impacts of sustainability will also find the framework and methods presented in this thesis useful. Other ideas for future work that are outside the scope of this thesis are noted accordingly:

- From the framework proposed in Chapter 8, researchers may wish to develop appropriate baselines for different industry sectors so that additionality can be measured more prominently.
- Further work is required to investigate the effects of uncertainty propagation arising from different scenarios (i.e. assuming correlation between criteria and use of different scoring scales)
- In addition, it will also be interesting to observe differences in the reaction of users/ practitioners in interpreting deterministic reporting versus one which incorporates uncertainty. These findings will prove useful in the ongoing development of the next generation of SRTs, such as integrated reporting.
- A majority of mainstream SRTs do not adequately account for interrelationships that exist in the supply chain. Developing a framework which accounts for sustainability in supply chain will have merit.
- Measuring the sustainability performance of buildings/infrastructure is only one part of the picture. Financial incentives or 'green' building funds from governments or private institutions may encourage building owners to retrofit their buildings to

achieve certain efficiency standards. Anecdotally, such funds do not appear to interlock with SRTs. The criteria and method used to gauge the suitability of recipients of such funds need to be re-examined in much more detail.

- Chapter 11 proposes criteria to measure PSML. Future research may wish to look into validating the usefulness of these criteria with project practitioners.
- The relevance of current reporting frameworks (i.e. GRI) to businesses in driving performance and to investors in evaluating investment decisions need to be investigated with more rigour.

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Appendix A. Frameworks for CSR reporting

No.	Papers	Author(s)	Contribution	Link
1	Revisiting a Corporate Sustainability Framework in an Integrated Reporting Era: A Diversified Resources Firm Perspective.	Lodhia and Martin, 2012	Suggest integrated sustainability criteria to enable integrated reporting.	http://mams.rmit.edu.au/fmcbjd8rlgvw1.pdf
2	Integrating Corporate Social Responsibility into ISO Management System – In Search of a Feasible CSR Management System Framework.	Castka et al., 2004	CSR framework based on process and systems thinking and analogous to ISO 9001.	http://www.emeraldinsight.com/journals.htm?articleid=842110&show=abstract
3	Designing and Implementing Corporate Social Responsibility: An Integrative Framework Grounded in Theory and Practice.	Maon et al., 2009	Nine steps for CSR design and implementation process.	http://www.springerlink.com/content/10261740n1u64n13/
4	Developing a Framework for Sustainable Development Criteria for the Mining and Minerals Industry.	Azapagic, 2004	Suggest a framework for performance assessment and improvements, specifically in the mining industry.	http://www.sciencedirect.com/science/article/pii/S0959652603000751
5	An Extended Performance Reporting Framework for Social and Environmental Accounting.	Yongvanich and Guthrie, 2006	Extend on three reporting approaches – intellectual capital (IC), balanced scorecard as well as social and environmental reporting.	http://onlinelibrary.wiley.com/doi/10.1002/bse.541/abstract
6	Extended Performance Reporting: Evaluating Corporate Social Responsibility and Intellectual Capital Management.	Guthrie et al., 2007	Extend performance reporting framework to the Australian food and beverage industry.	http://iiste.org/Journals/index.php/ISEA/article/view/890
7	Discovering Patterns in Corporate Social Responsibility (CSR) Reporting: A Transparent Framework Based on the GRI's Sustainability Reporting Guideline.	Everaert et al., 2009	Two-dimensional framework based on GRI and different types of disclosures: Values and Principles, Management Approach and Future Plans.	http://www.feb.ugent.be/nl/Ondz/WP/Chapters/wp_09_557.pdf

Table A1. Frameworks for CSR reporting (continued).

8	Green accounting ─ A New Dimension in the Performance and Activity Reporting of the Enterprise.	Man and Gadau, 2011	Expands on the concept of performance beyond the financial criteria and more towards social and environmental criteria.	http://anale-economie.spiruharet.ro/files/anale/Issue2_2011.pdf#page=149
9	Towards a Balanced CSR Performance Management Framework.	Panayiotou, 2007	Suggest CSR performance measurement framework based on the adoption of the BSC.	http://arvis.simor.ntua.gr/Attachments/Publications/Conferences/meperilipsistapraktika/7.8.4_TOWARDS%20A%20BALANCED%20CSR%20PERFORMANCE%20MEASUREMENT%20FRAMEWORK.pdf
10	Environmental Sustainability Criteria: A Reporting Tool of Corporate Social Responsibility.	Lungu, 2011	Outline of key environmental sustainability criteria.	http://fse.tibiscus.ro/anale/Lucrari/115.pdf
11	Criteria of Sustainable Development for Industry: A General Framework.	Azapagic and Perdan, 2000	Framework provides link between macro and micro aspects of sustainable development.	http://www.sciencedirect.com/science/article/pii/S0957582000708834
12	Evaluating the Sustainability of Complex Socio-Environmental Systems – The MESMIS Framework.	Ridaura et al., 2002	A cyclic framework which integrates evaluation into decision making and improves the likelihood of success in the implementation of developmental projects.	http://www.sciencedirect.com/science/article/pii/S1470160X02000432
13	Sustainability Accounting – A Brief History and Accounting Framework.	Lamberton, 2005	A review of sustainability accounting framework.	http://www.sciencedirect.com/science/article/pii/S0155998204000808
14	Measuring Strategic Environmental Performance.	Azzone and Manzini, 1994	Developed a set of information which can be used for managerial control focussed on the environmental performance of an industrial firm.	http://onlinelibrary.wiley.com/doi/10.1002/bse.3280030101/abstract
15	Sustainability in Action: Identifying and Measuring Key Performance Drivers.	Epstein and Roy, 2001	Framework describes drivers of corporate social performance, the actions managers can take and consequences of those actions.	http://www.sciencedirect.com/science/article/pii/S002463010100084X

Table A1. Frameworks for CSR reporting (continued).

16	Environmental Criteria for Business: A Review of the Literature and Standardisation Methods.	Olsthoorn et al., 2001	Proposes that environmental information can fall into one of the following: economic criteria, physical impact criteria, linear programming methods and economic valuation methods.	http://www.sciencedirect.com/science/article/pii/S0959652601000051
17	The Link between 'Green' and Economic Success: Environmental Management as the Crucial Trigger between Environmental and Economic Management.	Schaltegger and Synnestvedt, 2002	Presents theoretical framework to explain co-existence of two views (environmental performance causes extra costs and at the same time improved performance) – argue that both environmental performance and management are important.	http://www.sciencedirect.com/science/article/pii/S0301479702905554
18	Measuring Corporate Sustainability.	Atkinson (2000)	Provides practical advice on how businesses can adapt and improve current environmental accounting and reporting practices.	http://www.tandfonline.com/doi/abs/10.1080/09640560010694
19	Evaluation of Corporate Environmental Management Approaches: A Framework and Application.	Vastag et al. (1996)	Proposes that environmental risks are evaluated using two dimensions: endogenous from internal operations of company and exogenous from a company's external world such as location, ecological setting and demographic characteristics.	http://www.sciencedirect.com/science/article/pii/0925527396000400

Table A1. Frameworks for CSR reporting.

Appendix B. Analysis of selected corporate SRTs

No.	SRT	Framework (F), Standards (S) or Scores and Indices (SI)	Nature of SRT		Comments
			Deterministic scoring for criteria	Weighting	
1	GRI	F	X	N/A	Provides a comprehensive reporting framework for environmental, social and governance disclosures. Several versions of the framework exist now. There are three application levels, namely A, B and C depending on a company's extent of disclosures and also takes into account whether the report produced has received third party verification in which case it will be given a '+'.
2	DJSI	SI	X	N/A	Uses SAM's questionnaire to determine the inclusion of companies in this index.
3	CDP	F	X	N/A	Database containing information relating to greenhouse gas emissions, water use and climate change strategies. Carbon disclosures scores normalised to a 100 point scale.
4	ISO 14001	S	N/A	N/A	Provides a generic requirement for environmental management systems.
5	KLD	SI	X	N/A	Adopts a binary scale to indicate the absence or presence of an issue across several criteria.
6	EIRIS	SI	X	Optional	A framework covering approximately 87 criteria (environmental, social and governance)

Table B1. Analysis of selected corporate SRTs (continued).

7	SAM	SI	N/A	N/A	A set of questionnaires distributed annually to gauge the sustainability performance of companies.
8	MSCI ESG Indices	SI	X	N/A	Investment decision support tool for pension and hedge funds.
9	FTSE4Good Indices	SI	X	N/A	Uses EIRIS's framework to determine the inclusion of companies in this index.
10	ASR	SI	X	N/A	A framework containing approximately more than 100 criteria, and assessments of companies are done solely based on publicly-available information.

Table B1. Analysis of selected corporate SRTs.

Appendix C. International standards and frameworks embedded

International Standards/Framework	ASPI	Calvert	DJSI	Ethibel	FTSE4Good	KLD Domini 400	Accountability	Asset4	ECP	EIRIS	Innovest	KLD	oekom	SAM	SiRi	Viego
EFQM Excellence Model															√	
OECD Guidelines for Multinational Enterprises	√	√	√	√	√					√	√		√	√		√
UN Global Compact				√			√	√		√	√		√		√	
UN PRI			√			√		√		√	√		√		√	
UN Declaration of Human Rights	√	√	√	√	√			√	√	√	√		√	√	√	√
SA8000					√						√		√			
AA1000							√			√						
ISO14000			√		√	√				√	√	√	√	√	√	√
ISO9000										√			√		√	
EMAS			√		√								√	√		
ILO Core Labour Standards	√	√	√	√	√				√	√	√		√	√	√	√
OHSAS						√						√			√	
Kyoto Protocol	√		√	√						√			√			√
Millennium Development Goals (MDG)	√			√												√
Agenda 21	√		√	√												√
Rio Declaration	√		√	√							√					√
UN Charter and Treaties	√			√												√
International Financial Reporting Standards (IFRS)								√								
International Codes of Corporate Governances								√								
NGOs	√		√	√	√			√	√		√		√	√	√	√

Table C1. International standards and frameworks embedded (Escrig-Olmedo et al., 2010).

Appendix D. Qualitative criteria for GRI

Criteria	Code	Description
Economic Performance	EC2	Financial implications and other risks and opportunities for the company's activities due to climate change.
	EC3	Coverage of the company's defined benefit plan obligations.
	EC4	Significant financial assistance received from government.
Biodiversity	EN12	Description of significant impacts of activities, products, and services on biodiversity in protected areas and areas of high biodiversity value outside protected areas.
	EN13	Habitats protected or restored.
	EN14	Strategies, current actions, and future plans for managing impacts on biodiversity.
Emissions, Effluents and Waste	EN18	Initiatives to reduce greenhouse gas emissions and reductions achieved.
Employment	LA3	Benefits provided to full-time employees that are not provided to temporary or part-time employees, by major operations.
Occupational Health and Safety	LA8	Education, training, counselling, prevention, and risk-control programs in place to assist workforce members, their families, or community members regarding serious diseases.
	LA9	Health and safety topics covered in formal agreements with trade unions.
Training and Education	LA11	Programs for skills management and lifelong learning that support the continued employability of employees and assist them in managing career endings.
Child Labour	HR6	Operations identified as having significant risk for incidents of child labour, and measures taken to contribute to the elimination of child labour.
Customer Health and Safety	PR1	Life cycle stages in which health and safety impacts of products and services are assessed for improvement, and percentage of significant products and services subject to such procedures.

Table D1. Qualitative criteria for GRI.

Appendix E. Global market interest on ESG data

Variable	Hits
ESG disclosure score	2,395,230
GHG scope 1	1,520,488
Governance disclosure score	1,337,708
Environmental disclosure score	1,238,417
GHG scope 2	1,067,085
Social disclosure score	978,541
Total GHG emissions	920,170
% Independent directors	899,148
GHG scope 3	890,932
Size of the board	735,853
Number of independent directors	651,913
Verification type	645,330
UN Global Compact signatory	606,998
Board meeting % attendance	540,427
Number of board meetings for the year	519,099
CEO duality	508,482

Table E1. Global market interest on ESG data (Eccles et al., 2011)

Appendix F. LCA tools

No.	LCA tool	Developer	Weblink	Coverage	Outputs/Types of analysis
1	BEES	National Institute of Standards and Technology (NIST)	http://ws680.nist.gov/bees/(A(7rkOp_kyzgEkAAAAZWExZWEwZDItMzBiYS00YTVlLWJhYmUtN2NiOTc4MzNmY2YwJt9Z32gVssFf9Qf_Ghok1rCVQig1))/default.aspx	All stages in the life of a product (raw material acquisition, manufacture, transportation, installation, recycling, waste management).	• Economic performance measured using standard life cycle cost method. • Economic and environmental performance combined into one overall performance using multi-attribute decision analysis.
2	BOUSTEAD	BOUSTEAD Consulting UK	http://www.boustead-consulting.co.uk/	LCA tool across a number of categories (fuel production, fuel use, process, transport, biomass).	• Global warming potential. • Conservation of fossil fuels. • Acidification. • Grid electricity use. • Public water use.
3	ENVEST	Edge Environment	http://edgeenvironment.com.au/envest/	LCA tool for earlier phase of building design.	• Reveals operational impacts and embodied impacts of building as design evolves. • Provides estimates of construction cost and whole life cycle cost.
4	Ecoinvent	Ecoinvent Centre	http://www.ecoinvent.org/database/	Contains datasets in the area of agriculture, energy supply, transport, biofuels, construction materials, metals processing, electronics and waste treatment.	• Life cycle inventory which can be used with other major LCA tools

Table F1. LCA tools (continued).

5	GaBi	PE International	http://www.gabi-software.com/australia/software/gabi-software/gabi-5/	Users have the flexibility to construct life cycle of products at any stage.	• Life cycle assessment across different modules (design for environment, eco-efficiency, eco-design, efficient value chains) • Life cycle cost (designing and optimising products and services for cost reduction) • Life cycle reporting with modules across sustainable product marketing, sustainability reporting and LCA knowledge sharing • Life cycle working environment (developing manufacturing processes that address social responsibilities)

Table F1. LCA tools.

Appendix G. Comparison of criteria across SRTs

Criterion	Subcriterion	BREEAM	LEED	Green Star	CASBEE	ASPIRE	BCA Green Mark for Districts	EPRA	Estidama Pearl Community	Green Globe	Sustainable Design Scorecard	BEAM	DGNB-Seal	Protocol ITACA	AGIC
Environmental	Energy	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Water	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Waste	x	x	x	x		x	x	x	x	x	x		x	x
	Pollution/ Emissions/Air	x	x	x	x	x	x	x	x	x		x	x		x
	Land use and ecology	x	x	x	x	x	x	x	x	x		x	x		x
	Biodiversity	x	x	x	x	x	x		x				x		x
	Materials	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Social	Management (i.e. integrated process, sustainable procurement etc).	x		x	x	x		x	x	x		x			x
	Health and well-being/ IEQ	x	x	x		x	x	x	x	x	x	x	x	x	x
Economic	Innovation	x	x	x				x	x			x			x
	Equity of economic opportunity					x									
	Livelihood opportunity					x									
	Macroeconomic effects					x							x		

Table G1. Broad comparison of criteria across a selection of SRTs.

Appendix H. Analysis of building/infrastructure SRTs

SRT	Owner	Weblink	Nature of SRT		Comments
			Deterministic scoring for criteria	Weighting for criteria	
BREEAM	Building Research Establishment, UK	http://breeam.org	X	X	Environmental weightings exist and allocated to the 10 criteria identified; management, waste, health and well-being, energy, transport, water, pollution, land use and ecology, materials and innovation.
LEED	United States Green Building Council	http://www.usgbc.org	X	X	Similarities with BREEAM. The management criterion is not present in LEED.
Green Star	Green Building Council Australia	https://www.gbca.org.au/green-Star	X	X	Similar to BREEAM in terms of all the criteria assessed.
CASBEE	Japan Green Building Council and Japan Sustainable Building Consortium	http://www.ibec.or.jp	X	X	Applies the concept of eco-efficiency. Based on BEE = Q/L where Q represents quality and L represents load.
ASPIRE	ARUP and EAP	http://engineersagainstpoverty.com/major initiatives/aspire.cfm	X	N/A	Scores are guided by illustrations of best case and worst case scenarios. Traffic light idea where green indicates strength and red indicates weakness.

Table H1. Analysis of building/infrastructure SRTs (continued).

AGIC	Australian Green Infrastructure Council	http://www.agic.net.au/AGICschem.htm	X	N/A	An infrastructure assessment tool, launched in 2012. Scores < 25 points not eligible for certified award, 25 to < 50 points – Good, 50 to < 75 points – Excellent and 75 to 100 points – Leading.
BCA Green Mark for Districts	Building & Construction Authority, Singapore	http://www.bca.gov.sg/GreenMark/green_mark_buildings.htm	X	N/A	Embedded weightings are present. 'Green' buildings within district (where 25% allocated for Platinum, 20% for Gold Plus and 10% for Gold).
EPRA Sustainability Assessment Tool	East Perth Redevelopment Authority & GHD, WA	http://www.epra.wa.gov.au/	X	X	Utilises Green Star awards and tiering (i.e. Development in Tier one: 6 Star Green Star, Tier two: 5 Star Green Star, Tier three: 4 Star Green Star).
Estidama Pearl Community	Abu Dhabi Urban Planning Council (UPC)	http://www.estidama.org/	X	N/A	Scoring awarded at three different stages: design, construction and operational.
Green Globe	Green Globe International	http://www.greenglobe.org/	X	N/A	Quite similar to BREEAM, LEED and Green Star in terms of criteria accessed.
Sustainable Design Scorecard	Moreland City Council	http://www.portphilip.vic.gov.au	X	N/A	Based on aggregated scoring. Allocated points for environmental criteria have been weighted to be in line with Council's sustainability compliance priorities.
HK-BEAM	Hong Kong Beam Society	http://www.mixtechnology.com/files/download/HK_BEAM.pdf	X	X	Scores are allocated to each assessment criterion taking into account international consensus. Weightings exist for different criteria.
DGNB-Seal	German Sustainable Building Council	http://www.dgnb.de/_en/certification-system/Evaluation/evaluation.php	X	X	Each criterion receives a maximum of 10 points based on documented or calculated quality. There is flexibility to increase the weighting of each criterion by as much as threefold. Three performance standards: Gold (80%), Silver (50%) or Bronze (35%).
Protocol ITACA	ITACA	http://www.irbdirekt.de/daten/iconda/CIB9084.pdf	N/A	N/A	All performance criteria are set within performance scales from -2 to +5, where 0 is the minimum acceptable performance in the industry. The overall score is also based on this similar rating scale.

Table H1. Analysis of building/infrastructure SRTs.

Appendix I. International standards

International standard	BREEAM	LEED	Green Star	CASBEE	ASPIRE	AGIC	BCA Green Mark	EPRA	Estidama	Green Globe	Sustainable Design Scorecard	HK-BEAM	DGNB Seal	Protocol ITACA
ISO 14001	√		√			√	√	√	√	√		√	√	
ISO 9001	√					√								
AS/NZS 4804						√								
EMAS	√													
OHSAS 18001												√		

Table I. International standards embedded into building/infrastructure SRTs.

Appendix J. Financial performance formulae

Measure	Formula
Return on equity (ROE)	$\frac{\text{Net profit after tax}}{\text{Shareholders equity} - \text{Outside equity interest}}$
Return on assets (ROA)	$\frac{\text{Net profit after tax}}{\text{Total assets} - \text{Outside equity interests}}$
Return on invested capital (ROIC)	$\frac{\text{Net operating profit less adjusted taxes}}{\text{Operating invested capital before goodwill}}$
Earnings before interest tax depreciation and amortisation (EBITDA) margin	$\frac{\text{EBITDA}}{\text{Operating revenue}}$
Net operating profit less adjusted taxes (NOPLAT)	$\frac{\text{NOPLAT}}{\text{Operating revenue}}$
Earnings per share (EPS)	$\frac{\text{Net profit after tax} - \text{Preference dividends}}{\text{Average number of ordinary shares}}$
Dividend per share (DPS)	$\frac{\text{Ordinary dividends}}{\text{Number of ordinary shares}}$
Dividend yield (DY)	$\frac{\text{Dividend per share}}{\text{Market price per share}}$
Price to earnings ratio (PER)	$\frac{\text{Market price per share}}{\text{Earnings per share}}$
Market capitalisation to trading revenue ratio (MC/TR)	$\frac{\text{Market capitalisation}}{\text{Trading revenue}}$
Enterprise value (EV)	$\text{Common equity} + \text{Debt} + \text{Minority interest} + \text{Preferred equity} - \text{Cash}$
Price to book value (P/BV)	$\frac{\text{Closing share price}}{\text{Shareholders equity per share}}$

Table J. Financial performance formulae.

Appendix K. Probabilities of stock price movement

Company	π_1 ($x \leq \$0$)	π_2 ($\$0 < x \leq \$0.1$)	π_3 ($x > \$0.1$)
1	0.48	0.234	0.285
2	0.495	0.0456	0.459
3	0.487	0.128	0.384
4	0.449	0.0987	0.452
5	0.505	0.193	0.301
6	0.462	0.0229	0.515
7	0.497	0.289	0.212
8	0.51	0.382	0.107
9	0.475	0.0686	0.455
10	0.475	0.0468	0.478
11	0.51	0.292	0.193
12	0.484	0.0307	0.484
13	0.543	0.121	0.336
14	0.481	0.0428	0.476
15	0.486	0.497	0.0157
16	0.529	0.0667	0.403
17	0.479	0.467	0.0527
18	0.472	0.413	0.114
19	0.535	0.217	0.247
20	0.51	0.23	0.26
21	0.503	0.379	0.118
22	0.505	0.334	0.16
23	0.485	0.158	0.355
24	0.397	0.218	0.383
25	0.52	0.0468	0.432
26	0.538	0.462	0
27	0.52	0.205	0.275
28	0.513	0.114	0.373
29	0.477	0.477	0.045

Table K1. Probabilities of stock price movement (price difference) from10-day moving average, three states.

Company	π_1 (x ≤ 0%)	π_2 (0% < x ≤ 0.5%)	π_3 (x > 0.5%)
1	0.48	0.077	0.43
2	0.5	0.055	0.44
3	0.48	0.099	0.42
4	0.478	0.0837	0.438
5	0.504	0.072	0.424
6	0.476	0.063	0.45
7	0.504	0.135	0.36
8	0.515	0.078	0.405
9	0.472	0.0828	0.448
10	0.469	0.0542	0.476
11	0.51	0.064	0.426
12	0.481	0.062	0.457
13	0.534	0.0666	0.399
14	0.493	0.048	0.457
15	0.505	0.0975	0.396
16	0.542	0.0667	0.39
17	0.476	0.0901	0.434
18	0.474	0.097	0.428
19	0.55	0.0597	0.389
20	0.532	0.0876	0.38
21	0.526	0.0558	0.418
22	0.523	0.0776	0.399
23	0.489	0.0707	0.44
24	0.486	0.114	0.4
25	0.518	0.0769	0.404
26	0.524	0.0811	0.395
27	0.536	0.0579	0.406
28	0.52	0.072	0.39
29	0.487	0.075	0.438

Table K2. Probabilities of stock price movement (price difference in percentage) from 10-day moving average, three states.

Company	π_1 ($x \leq 0\%$)	π_2 ($0\% < x \leq 0.5\%$)	π_3 ($0.5\% < x \leq 1\%$)	π_4 ($x > 1\%$)
1	0.482	0.077	0.071	0.379
2	0.492	0.052	0.055	0.4
3	0.483	0.099	0.091	0.327
4	0.446	0.077	0.083	0.393
5	0.504	0.0718	0.0809	0.343
6	0.463	0.061	0.042	0.434
7	0.497	0.134	0.074	0.295
8	0.527	0.078	0.057	0.337
9	0.48	0.084	0.073	0.36
10	0.494	0.055	0.07	0.38
11	0.51	0.062	0.071	0.357
12	0.481	0.062	0.06	0.397
13	0.533	0.067	0.074	0.326
14	0.511	0.05	0.062	0.38
15	0.505	0.097	0.069	0.328
16	0.539	0.067	0.065	0.329
17	0.498	0.095	0.107	0.299
18	0.47	0.0973	0.106	0.324
19	0.544	0.059	0.0687	0.328
20	0.514	0.0839	0.0861	0.315
21	0.526	0.0557	0.0559	0.362
22	0.522	0.0776	0.0817	0.318
23	0.477	0.067	0.085	0.371
24	0.486	0.114	0.087	0.313
25	0.534	0.0806	0.0778	0.307
26	0.534	0.0833	0.0817	0.3
27	0.543	0.0577	0.0628	0.337
28	0.532	0.0736	0.0797	0.314
29	0.493	0.076	0.0683	0.363

Table K3. Probabilities of stock price movement (price difference in percentage) from 5-day moving average, three states.

Appendix L. Analysis of public pressure index

Figure L1 shows that public pressure index differs among selected US construction companies between January 2011 and June 2012.

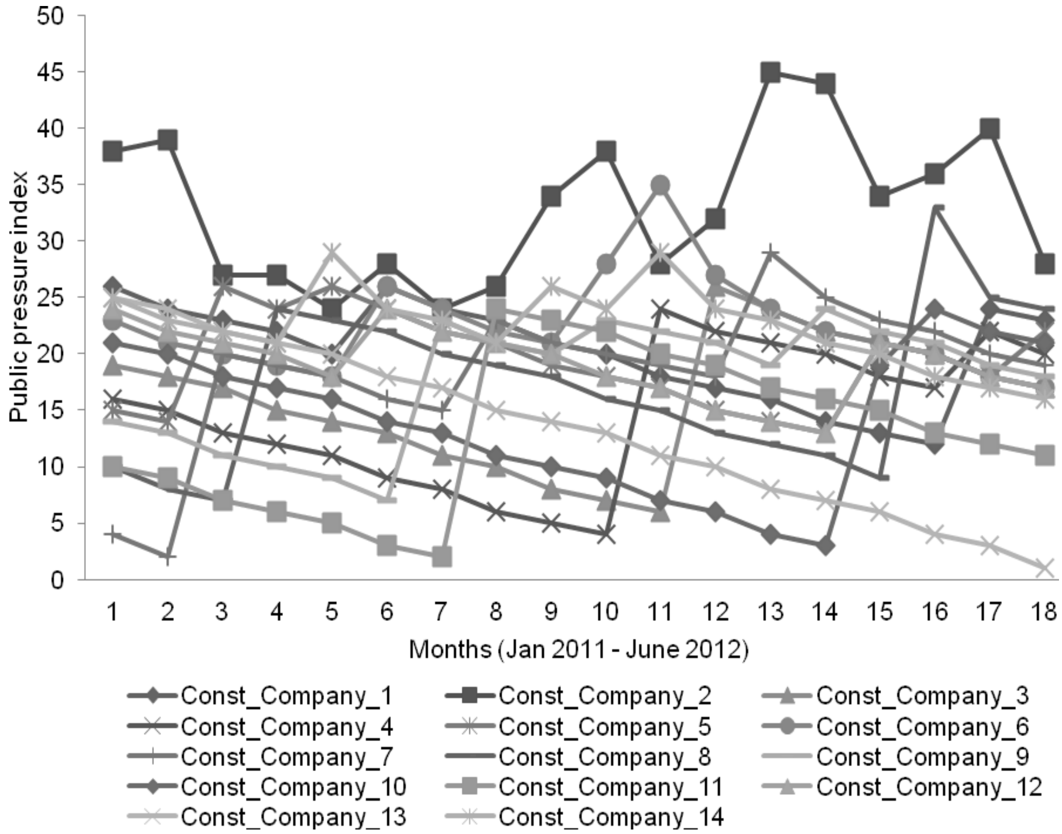

Figure L1. Public pressure index for selected US construction companies (Jan 2011 – June 2012)

The KPSS test is also used to gauge the null hypothesis that public pressure (or intensity of bad news) is stationary over time. The alternative hypothesis is that it is not (see Kwiatkowski et al., 1992 for detailed mathematical development of KPSS). Note that stationary here is used differently to that in Chapter 5. In the context here, if the results of the KPSS test demonstrate that public pressure index is stationary, then it means that the intensity of bad news concerning a company is a completely random process.

Company	KPSS test for stationarity	p-value	t-value
Const_Company_1	Stationary	0.0725	0.1339
Const_Company_2	Stationary	0.0596	0.1408
Const_Company_3	Non-stationary	0.0100	0.2183
Const_Company_4	Non-stationary	0.0100	0.2166
Const_Company_5	Non-stationary	0.0490	0.1473
Const_Company_6	Non-stationary	0.0100	0.2491
Const_Company_7	Non-stationary	0.0411	0.1567
Const_Company_8	Stationary	0.0671	0.1368
Const_Company_9	Non-stationary	0.0213	0.1859
Const_Company_10	Non-stationary	0.0100	0.3363
Const_Company_11	Non-stationary	0.0100	0.2266
Const_Company_12	Stationary	0.0931	0.1227
Const_Company_13	Stationary	0.100	0.0309
Const_Company_14	Non-stationary	0.0100	0.2320

Table L1. Stationarity of public pressure (US construction companies).

Figure L2 shows the difference in public pressure index for selected Australian construction companies between January 2011 and June 2012.

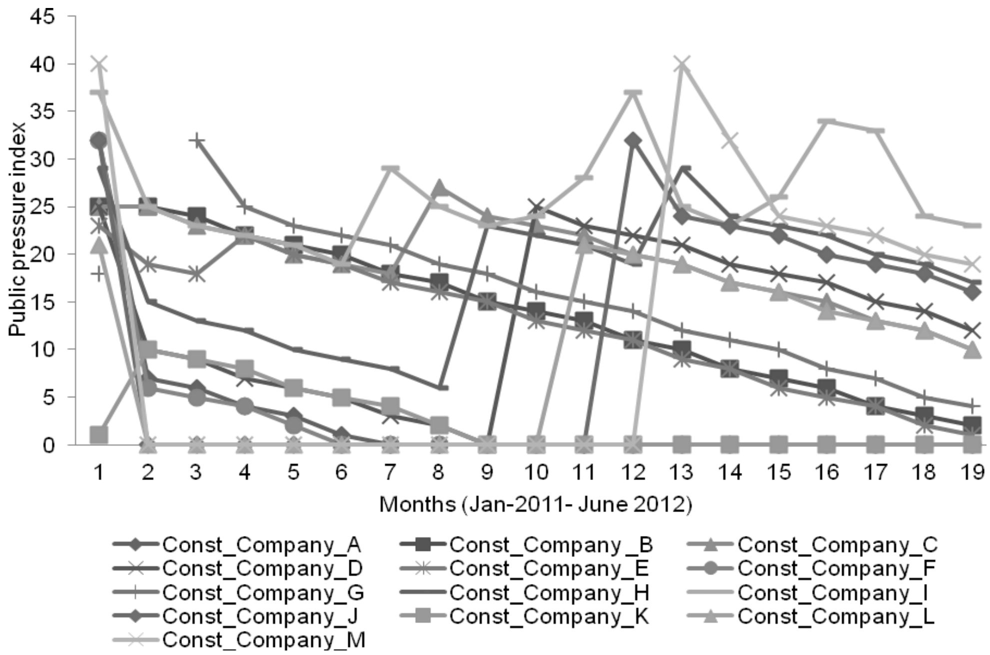

Figure L2. Public pressure index for selected Australian construction companies (Jan 2011 – June 2012)

Company	KPSS test for stationarity	p-value	t-value
Const_Company_A	Non-stationary	0.0100	0.3781
Const_Company_B	Stationary	0.100	0.0472
Const_Company_C	Non-stationary	0.0100	0.2672
Const_Company_D	Non-stationary	0.0248	0.1765
Const_Company_E	Non-stationary	0.0135	0.2065
Const_Company_F	Non-stationary	0.0100	0.3536
Const_Company_G	Stationary	0.100	0.0899
Const_Company_H	Non-stationary	0.0480	0.1484
Const_Company_I	Stationary	0.100	0.0698
Const_Company_J	Stationary	0.0644	0.1382
Const_Company_K	Non-stationary	0.0100	0.4415
Const_Company_L	Non-stationary	0.0201	0.1891
Const_Company_M	Stationary	0.0819	0.1288

Table L2. Stationarity of public pressure (Australian construction companies).

Appendix M. Survey (variation in scoring)

1. How well is the building project managed?

	1	2	3	4	5	6	7	8	9	10
Deterministic	○	○	○	○	○	○	○	○	○	○
Optimistic	○	○	○	○	○	○	○	○	○	○
Most Likely	○	○	○	○	○	○	○	○	○	○
Pessimistic	○	○	○	○	○	○	○	○	○	○

2. How well is the building designed to improve indoor environmental quality?

	1	2	3	4	5	6	7	8	9	10
Deterministic	○	○	○	○	○	○	○	○	○	○
Optimistic	○	○	○	○	○	○	○	○	○	○
Most Likely	○	○	○	○	○	○	○	○	○	○
Pessimistic	○	○	○	○	○	○	○	○	○	○

3. How well is the building designed to reduce energy consumption?

	1	2	3	4	5	6	7	8	9	10
Deterministic	○	○	○	○	○	○	○	○	○	○
Optimistic	○	○	○	○	○	○	○	○	○	○
Most Likely	○	○	○	○	○	○	○	○	○	○
Pessimistic	○	○	○	○	○	○	○	○	○	○

4. How well is the building designed to reduce emissions?

	1	2	3	4	5	6	7	8	9	10
Deterministic	○	○	○	○	○	○	○	○	○	○
Optimistic	○	○	○	○	○	○	○	○	○	○
Most likely	○	○	○	○	○	○	○	○	○	○
Pessimistic	○	○	○	○	○	○	○	○	○	○

5. How well is the building designed to use 'green' materials?

	1	2	3	4	5	6	7	8	9	10
Deterministic	○	○	○	○	○	○	○	○	○	○
Optimistic	○	○	○	○	○	○	○	○	○	○
Most likely	○	○	○	○	○	○	○	○	○	○
Pessimistic	○	○	○	○	○	○	○	○	○	○

6. What is the effort level in reducing environmental impact?

	1	2	3	4	5	6	7	8	9	10
Deterministic	○	○	○	○	○	○	○	○	○	○
Optimistic	○	○	○	○	○	○	○	○	○	○
Most likely	○	○	○	○	○	○	○	○	○	○
Pessimistic	○	○	○	○	○	○	○	○	○	○

7. How innovative is the design of the building?

	1	2	3	4	5	6	7	8	9	10
Deterministic	○	○	○	○	○	○	○	○	○	○
Optimistic	○	○	○	○	○	○	○	○	○	○
Most likely	○	○	○	○	○	○	○	○	○	○
Pessimistic	○	○	○	○	○	○	○	○	○	○

Appendix N. Experimental survey results

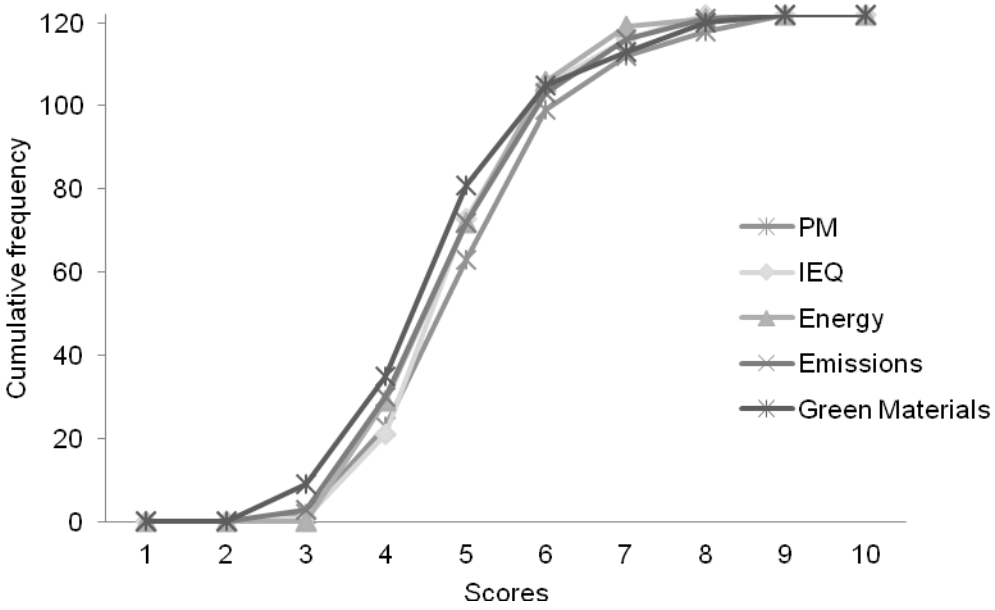

Figure N1. Experimental results – Building E, N = 122.

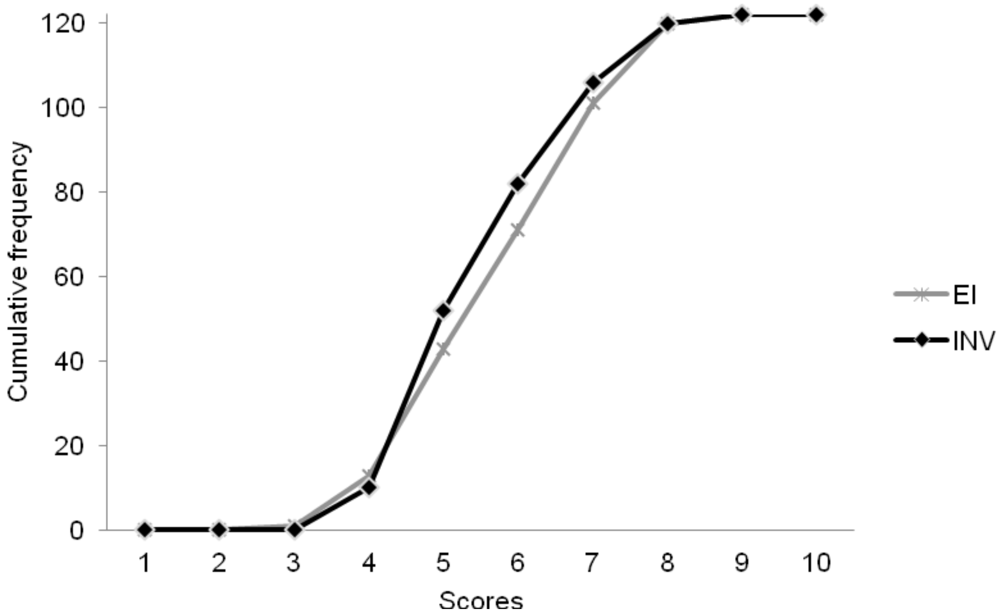

Figure N2. Experimental results – Building F, N = 122.

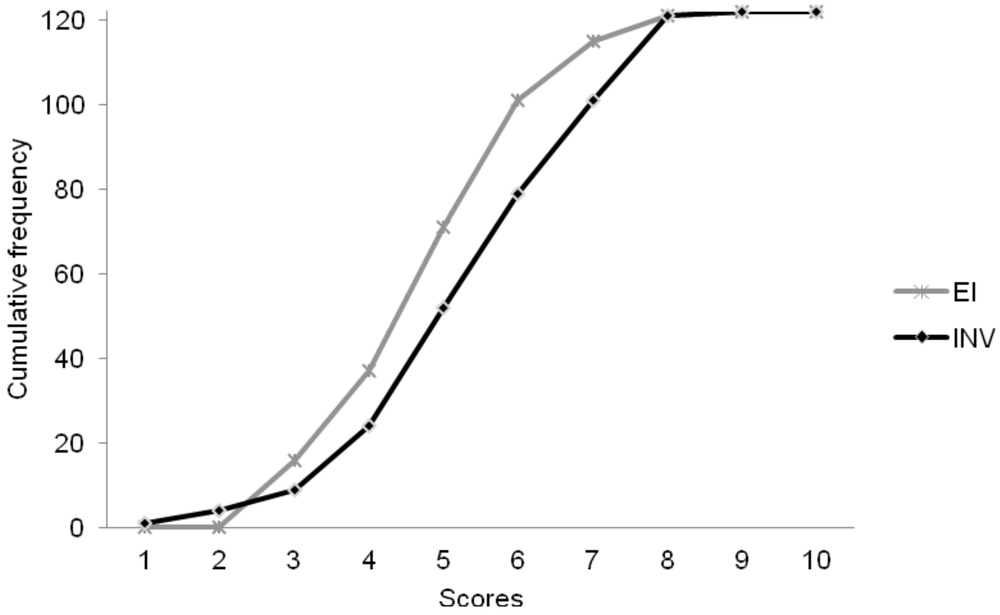

Figure N3. Experimental results – Building G, N = 122.

Appendix O. Boxplot analysis

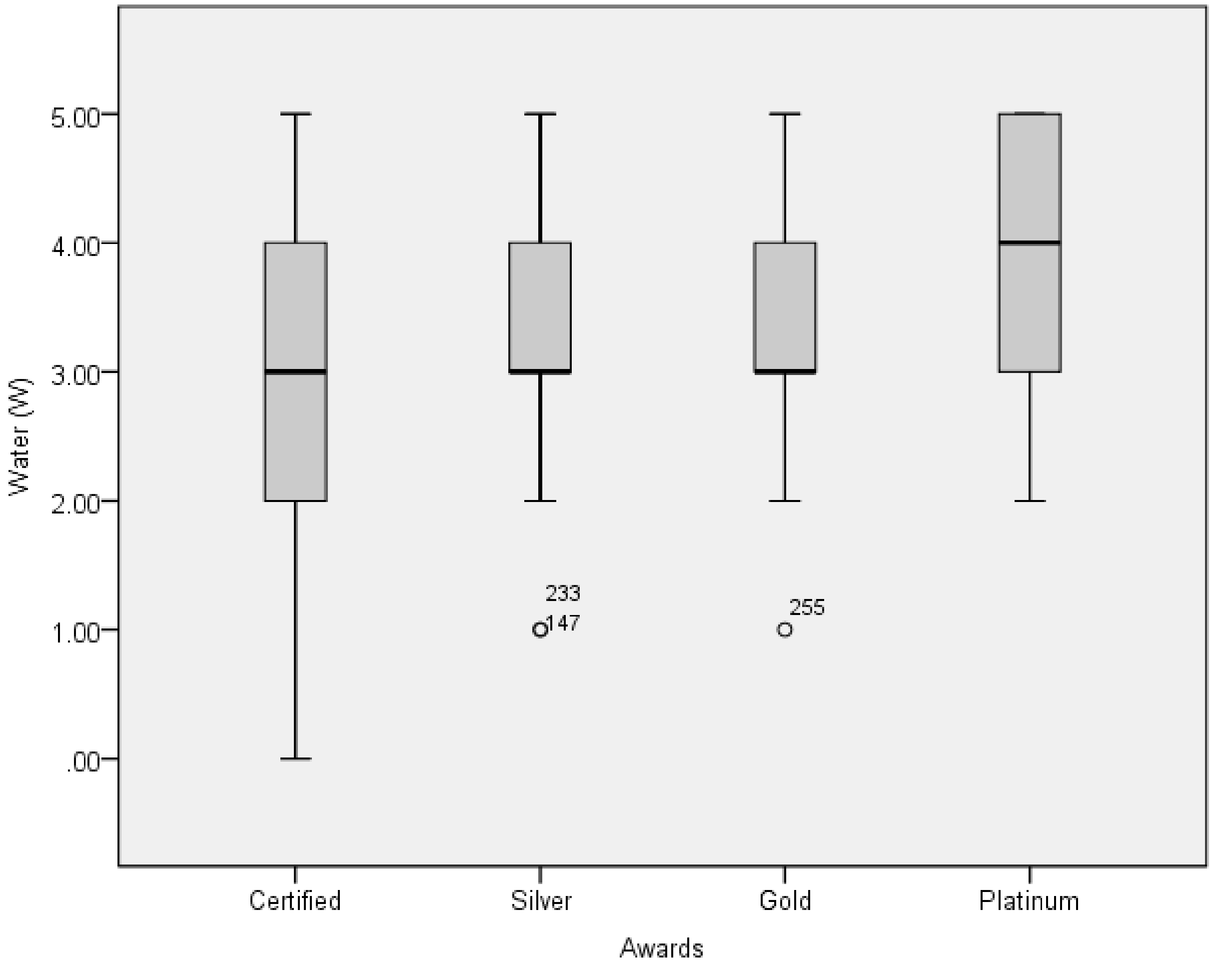

Figure O1. Boxplots of four LEED awards (certified, silver, gold and platinum) based on the water criterion.

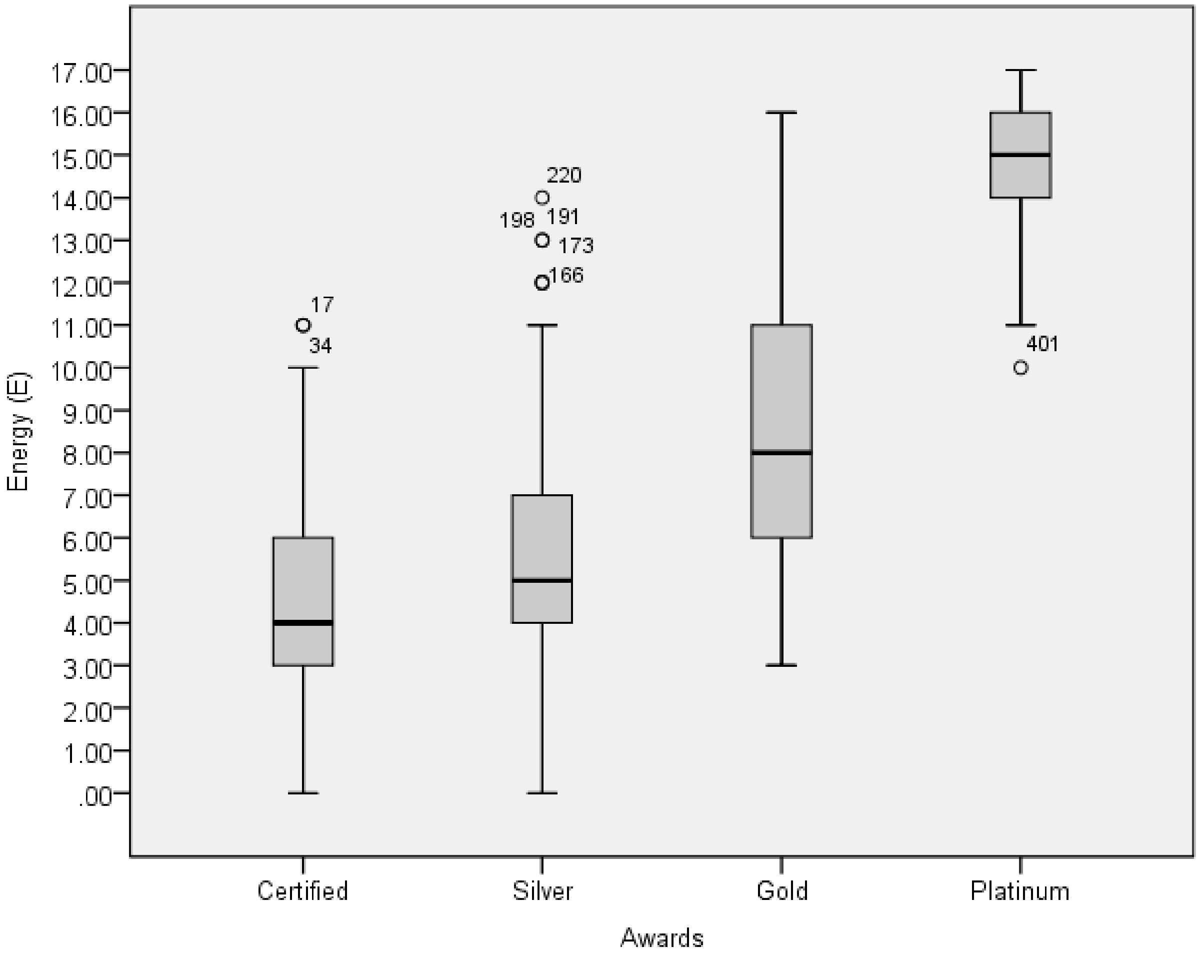

Figure O2. Boxplots of four LEED awards (certified, silver, gold and platinum) based on the energy criterion.

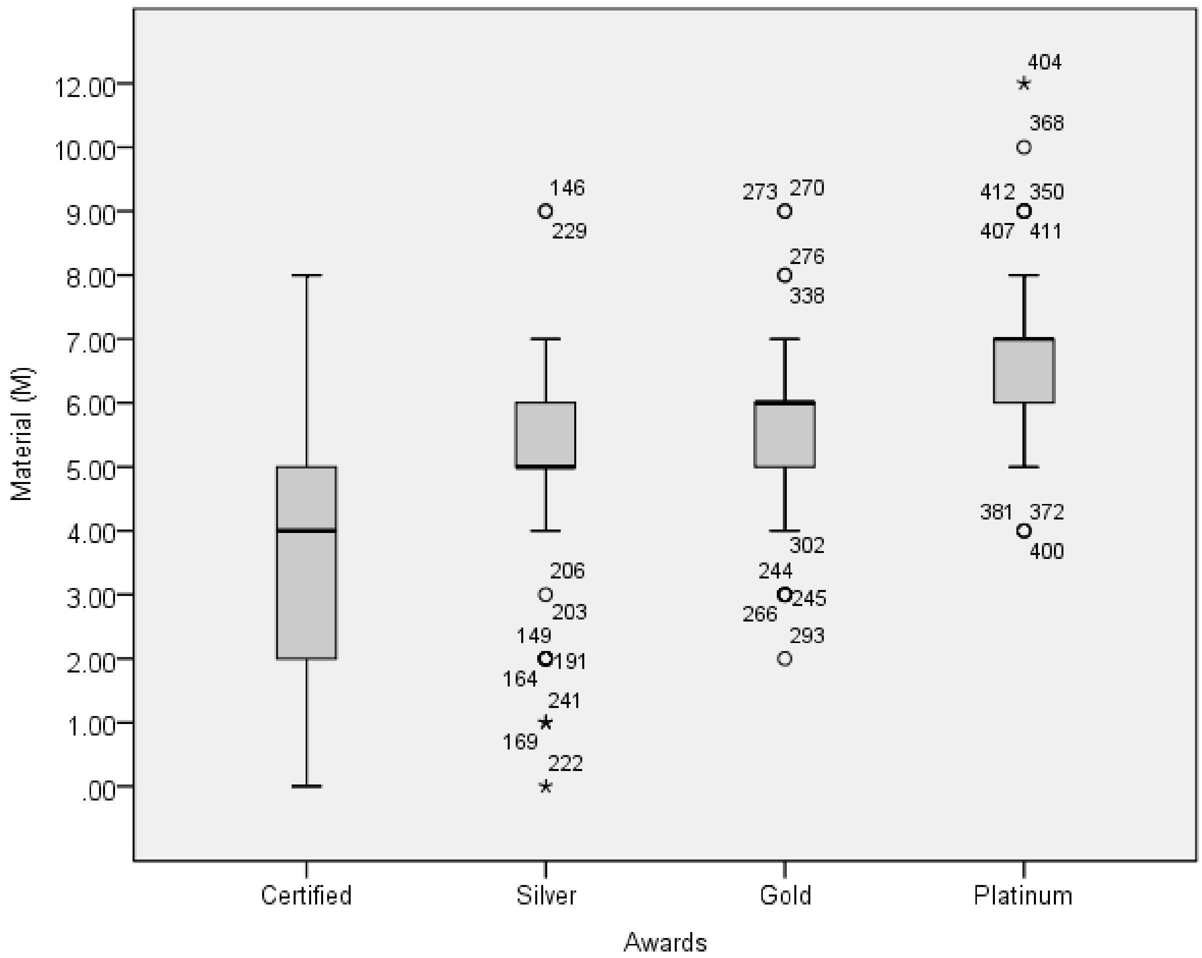

Figure O3. Boxplots of four LEED awards (certified, silver, gold and platinum) based on the material criterion. (The round symbols are outliers. These are defined as values that do not fall in the inner fences. Outliers are extreme values. The asterisks or stars are extreme outliers. They represent cases/rows that have values more than three times the height of the boxes).

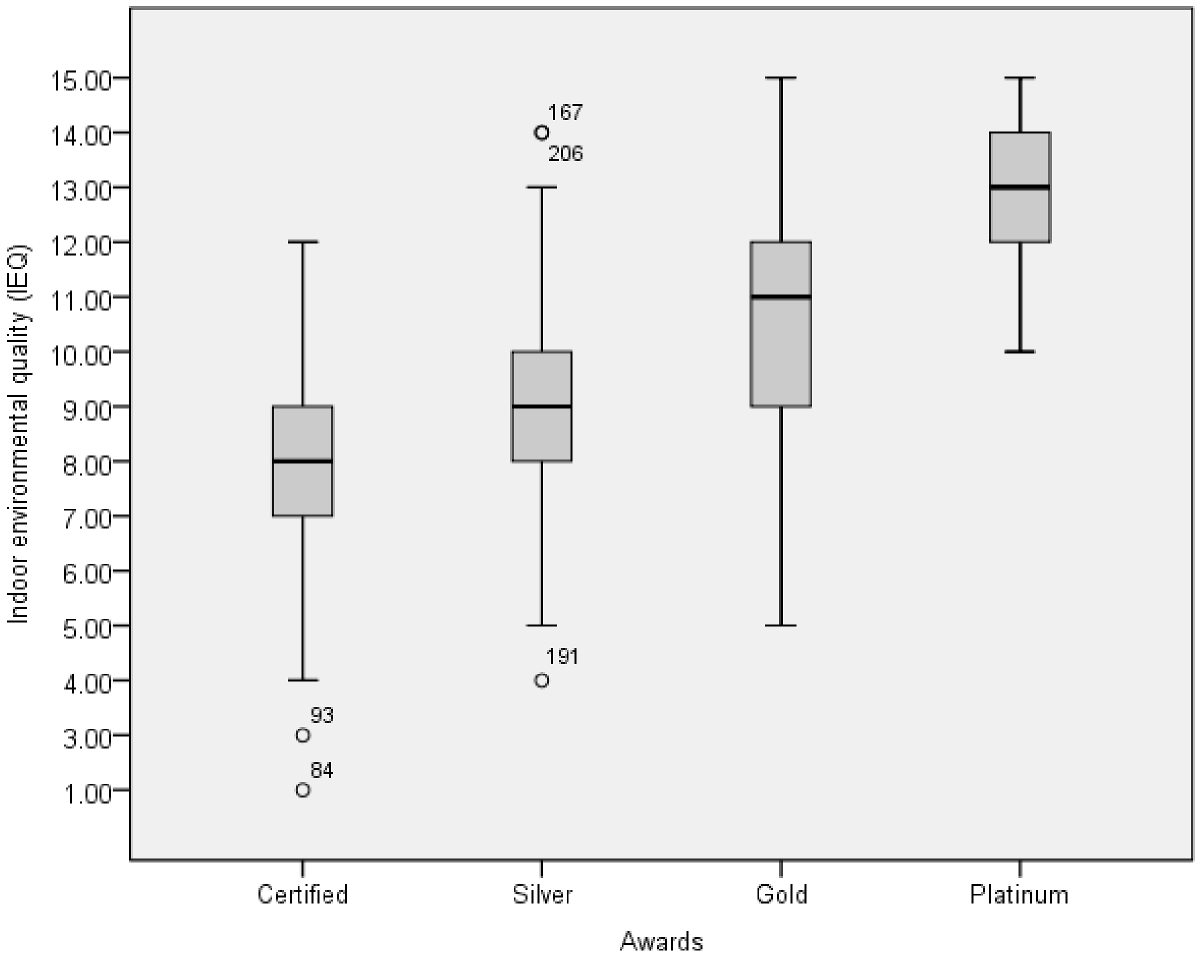

Figure O4. Boxplots of four LEED awards (certified, silver, gold and platinum) based on the indoor environmental quality (IEQ) criterion.

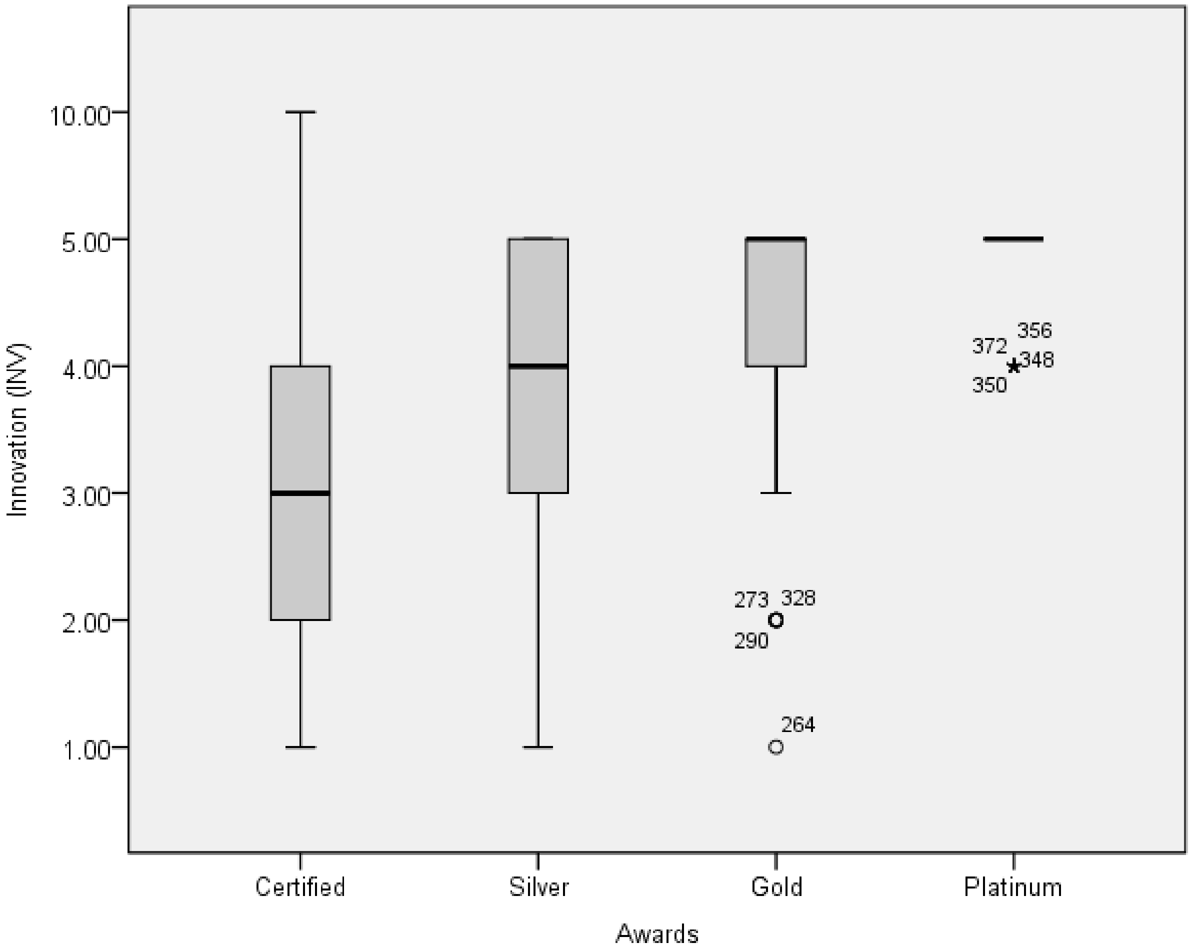

Figure O5. Boxplots of four LEED awards (certified, silver, gold and platinum) based on the innovation criterion.

Appendix P. Paired sample t-test

Criteria	Paired differences					t	df	Sig. (2-tailed)
	Mean	Std. deviation	Std. error mean	95% confidence interval of the difference				
				Lower	Upper			
PM	-0.502	0.631	0.057	-0.615	-0.389	-8.783	121.000	0.000
IEQ	-0.392	0.750	0.068	-0.526	-0.257	-5.772	121.000	0.000
Energy	-0.422	0.886	0.080	-0.581	-0.263	-5.260	121.000	0.000
Emissions	-0.414	0.799	0.072	-0.557	-0.270	-5.717	121.000	0.000
‘Green’ Materials	-0.418	0.794	0.072	-0.560	-0.275	-5.809	121.000	0.000

Table P1. Paired sample t-test for building A.

Criteria	Paired differences					t	df	Sig. (2-tailed)
	Mean	Std. deviation	Std. error mean	95% confidence interval of the difference				
				Lower	Upper			
PM	-0.581	0.739	0.067	-0.713	-0.448	-8.667	121	0.000
IEQ	-0.311	0.728	0.0659	-0.442	-0.181	-4.725	121	0.000
Energy	-0.418	0.690	0.0625	-0.542	-0.294	-6.69	121	0.000
Emissions	-0.318	0.622	0.0563	-0.429	-0.207	-5.64	121	0.000
Green Materials	-0.226	0.668	0.0604	-0.345	-0.106	-3.73	121	0.000

Table P2. Paired sample t-test for building B.

Criteria	Paired differences					t	df	Sig. (2-tailed)
	Mean	Std. deviation	Std. error mean	95% confidence interval of the difference				
				Lower	Upper			
PM	-0.318	0.659	0.0597	-0.436	-0.200	-5.334	121	0.000
IEQ	-0.327	0.715	0.0647	-0.455	-0.198	-5.050	121	0.000
Energy	-0.171	0.659	0.0597	-0.289	-0.0527	-2.863	121	0.005
Emissions	-0.260	0.602	0.0545	-0.368	-0.152	-4.768	121	0.000
Green Materials	-0.188	0.670	0.0607	-0.307	-0.0673	-3.088	121	0.002

Table P3. Paired sample t-test for building C.

Criteria	Paired differences					t	df	Sig. (2-tailed)
	Mean	Std. deviation	Std. error mean	95% confidence interval of the difference				
				Lower	Upper			
PM	-0.229	0.576	0.0521	-0.333	-0.126	-4.403	121	0.000
IEQ	-0.197	0.672	0.0608	-0.317	-0.076	-3.232	121	0.002
Energy	-0.0928	0.707	0.0640	-0.219	0.0339	-1.449	121	0.150
Emissions	-0.0478	0.579	0.0524	-0.151	0.0559	-0.912	121	0.363
Green Materials	0.0536	0.707	0.0639	-0.0731	0.1802	0.838	121	0.404

Table P4. Paired sample t-test for building D.

Criteria	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. deviation	Std. error mean	95% confidence interval of the difference				
				Lower	Upper			
PM	-0.491	0.860	0.0779	-0.645	-0.337	-6.302	121	0.000
IEQ	-0.375	0.714	0.0646	-0.503	-0.247	-5.808	121	0.000
Energy	-0.353	0.681	0.0616	-0.474	-0.231	-5.727	121	0.000
Emissions	-0.349	0.703	0.0636	-0.475	-0.223	-5.475	121	0.000
Green Materials	-0.332	0.647	0.0586	-0.448	-0.216	-5.667	121	0.000

Table P5. Paired sample t-test for building E.

Appendix Q. AHP results/Consistency ratio

Respondents	E	ENE	W	LUE	IEQ	T	MAT	MGT	INV	CR
1	0.387	0.254	0.089	0.089	0.035	0.035	0.035	0.035	0.035	0.055
2	0.315	0.240	0.144	0.085	0.042	0.052	0.046	0.038	0.039	0.107
3	0.381	0.196	0.077	0.075	0.048	0.051	0.079	0.051	0.041	0.101
4	0.396	0.184	0.101	0.080	0.045	0.057	0.055	0.050	0.032	0.099
5	0.289	0.226	0.138	0.084	0.073	0.062	0.044	0.042	0.042	0.077
6	0.361	0.194	0.121	0.061	0.078	0.047	0.065	0.029	0.043	0.097
7	0.253	0.255	0.048	0.087	0.100	0.070	0.081	0.057	0.049	0.093
8	0.221	0.273	0.185	0.069	0.047	0.063	0.055	0.046	0.042	0.076
9	0.236	0.180	0.216	0.077	0.077	0.051	0.056	0.056	0.051	0.090
10	0.209	0.225	0.080	0.101	0.151	0.074	0.063	0.053	0.044	0.084
11	0.256	0.190	0.098	0.088	0.153	0.052	0.049	0.060	0.053	0.096
12	0.104	0.186	0.109	0.127	0.092	0.104	0.085	0.104	0.089	0.050
13	0.283	0.209	0.127	0.103	0.071	0.042	0.047	0.060	0.058	0.098
14	0.126	0.275	0.121	0.135	0.101	0.068	0.068	0.064	0.042	0.083
15	0.314	0.179	0.094	0.073	0.093	0.116	0.046	0.054	0.030	0.108
16	0.143	0.244	0.098	0.076	0.064	0.118	0.068	0.086	0.102	0.075
17	0.291	0.089	0.125	0.067	0.084	0.102	0.068	0.074	0.100	0.097
18	0.264	0.278	0.067	0.082	0.077	0.076	0.051	0.057	0.047	0.100
19	0.411	0.190	0.106	0.076	0.052	0.048	0.045	0.034	0.038	0.091
20	0.266	0.156	0.073	0.081	0.073	0.137	0.065	0.068	0.080	0.100
21	0.175	0.228	0.085	0.119	0.067	0.068	0.068	0.099	0.090	0.093
22	0.246	0.190	0.071	0.071	0.139	0.071	0.082	0.064	0.064	0.086
23	0.357	0.123	0.074	0.102	0.156	0.057	0.051	0.044	0.036	0.095
24	0.349	0.209	0.067	0.079	0.058	0.055	0.080	0.056	0.046	0.096
25	0.237	0.200	0.076	0.194	0.145	0.037	0.042	0.037	0.032	0.069
26	0.345	0.240	0.124	0.076	0.053	0.038	0.040	0.043	0.041	0.089
27	0.241	0.266	0.143	0.087	0.071	0.049	0.049	0.050	0.045	0.065
28	0.394	0.223	0.112	0.061	0.041	0.059	0.037	0.037	0.036	0.103
29	0.235	0.264	0.148	0.079	0.055	0.076	0.049	0.050	0.044	0.069
30	0.251	0.230	0.099	0.071	0.065	0.094	0.062	0.067	0.062	0.048
31	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.000
32	0.202	0.227	0.172	0.098	0.066	0.057	0.054	0.071	0.054	0.090
33	0.247	0.307	0.153	0.088	0.047	0.048	0.036	0.031	0.043	0.089
34	0.377	0.193	0.116	0.103	0.063	0.043	0.035	0.029	0.040	0.097
35	0.414	0.190	0.109	0.090	0.058	0.041	0.032	0.028	0.038	0.099
36	0.277	0.186	0.121	0.106	0.100	0.055	0.053	0.056	0.046	0.084
37	0.289	0.196	0.132	0.102	0.091	0.049	0.044	0.053	0.042	0.106
38	0.215	0.345	0.127	0.077	0.071	0.042	0.042	0.044	0.037	0.106

Table Q1. Variation in criteria weights (sum of weights may not be exactly 1 due to rounding off errors). CR is the consistency ratio (continued)

39	0.396	0.180	0.126	0.052	0.051	0.046	0.046	0.042	0.062	0.082
40	0.297	0.181	0.076	0.049	0.063	0.090	0.101	0.086	0.057	0.099
41	0.229	0.211	0.142	0.092	0.057	0.097	0.053	0.063	0.057	0.081
42	0.208	0.176	0.221	0.070	0.069	0.069	0.072	0.058	0.058	0.093
43	0.213	0.290	0.238	0.043	0.040	0.064	0.035	0.039	0.039	0.090
44	0.185	0.159	0.121	0.152	0.074	0.070	0.085	0.091	0.062	0.103
45	0.152	0.273	0.133	0.118	0.078	0.055	0.068	0.058	0.064	0.063
46	0.178	0.229	0.255	0.051	0.051	0.050	0.053	0.064	0.068	0.089
47	0.276	0.279	0.129	0.071	0.070	0.045	0.048	0.039	0.044	0.095
48	0.135	0.217	0.181	0.121	0.091	0.096	0.080	0.042	0.038	0.090
49	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.000
50	0.246	0.110	0.232	0.096	0.063	0.086	0.061	0.056	0.050	0.093
51	0.164	0.115	0.172	0.102	0.117	0.128	0.073	0.068	0.062	0.082
52	0.326	0.193	0.143	0.073	0.058	0.051	0.060	0.047	0.048	0.096

Table Q1. Variation in criteria weights (sum of weights may not be exactly 1 due to rounding off errors). CR is the consistency ratio.

Appendix R. R code for agglomerative cluster analysis and CART.

R code for plotting dendrogram

```
> kldtaxonomy <read.table ("d:\\kldtaxonomy.txt",header=T)
> attach (kldtaxonomy)
>names (kldtaxonomy)
> plot (hclust(dist(kldtaxonomy)),main= "kldtaxonomy")
```

R code for determining properties of cluster solutions

```
> kldtaxonomy <read.table ("d:\\kldtaxonomy.txt",header=T)
> attach(kldtaxonomy)
>names (kldtaxonomy)
>as.matrix(kldtaxonomy)
>kldtaxonomy.dist = dist (kldtaxonomy)
>kldtaxonomy.hclust = hclust(kldtaxonomy.dist)
>counts = sapply (2:6, function (ncl) table (cutree(kldtaxonomy.hclust, ncl))
>names (counts) = 2:6
>counts
>aggregate (kldtaxonomy, list (groups.3), median)
>aggregate (kldtaxonomy, list (groups.3),mean)
```

R code for creating classification tree

```
> kldtaxonomy1 <read.table ("d:\\kldtaxonomy1.txt",header=T)
> attach (kldtaxonomy1)
>names (kldtaxonomy1)
>model1<-tree (Taxo~.,kldtaxonomy1)
>plot (model1)
>text (model1)
>summary (model1)
```

```
>print (model1)
```

R code for creating regression tree

```
> kldtaxonomy2 <read.table ("d:\\KLD_Tree_Generic)Cart_Model.txt",header=T)
> attach (kldtaxonomy2)
>names (kldtaxonomy2)
>model2<-tree (kldtaxonomy2)
>plot (kldtaxonomy2)
>text (kldtaxonomy2)
>print (model2)
>prune.tree (model2)
>model3<-prune.tree(model2, best=6)
>plot (model3)
>text (model3)
```

Appendix S. Sample data set for regression tree model preliminaries

Time (Years)	ESG values	
	Company A	Company B
1	80	0
2	40	2
3	12	2
4	10	2
5	9	3
6	3	9
7	3	13
8	2	38
9	2	42
10	0	50

Table S1. Data set for Company A and Company B.

Appendix T. Project sustainability maturity level (PSML)

A. Integration

A1. Project planning

Level 1	No planning done to review sustainability goals or initiatives. Sustainability initiatives are carried out in an ad hoc manner.
Level 2	Sustainability initiatives are planned during the initiation phase (start of the project). This planning takes into account the type and scale of the project.
Level 3	Sustainability initiatives are planned and documented in detail. Project management team monitors the planning process.
Level 4	Work done and conclusions from previous projects are used to improve future planning of sustainability initiatives. The planning process is clearly understood and every aspect of sustainability has been considered (environmental, social or economic).

Table T1. Different levels of maturity in project planning.

A2. Project execution

Level 1	Sustainability initiatives are only executed to solve problems momentarily.
Level 2	A structure is in place to identify parties responsible for executing different sustainability initiatives.
Level 3	The execution of sustainability initiatives are monitored by the project management team.
Level 4	A process is in place to review and improve the execution of sustainability initiatives. Close collaboration exists among other project teams.

Table T2. Different levels of maturity in project execution.

A3. Change control

Level 1	Changes to sustainability initiatives are not managed very well.
Level 2	There is a process in place to manage changes to sustainability initiatives although this may not be fully conducted across all projects.
Level 3	The project management team monitors changes that have been made to sustainability initiatives.
Level 4	Top management is proactively involved in managing any potential issues or problems that may arise as a result of changes in sustainability initiatives. Stakeholders are usually informed of such changes.

Table T3. Different levels of maturity in change control.

A4. Information handling

Level 1	No evidence of information storage. No database exists for collecting, organising or integrating sustainability information, processes and procedures.
Level 2	There is clear definition/boundary as to what sustainability information is stored in the database but very basic like a central filing tool.
Level 3	There is a central information database which collects, integrates, and organises sustainability related information, processes and procedures. Usually monitored by the project management team.
Level 4	A process is in place to improve the sustainability information database. Very frequent usage of this database as cross reference for future projects.

Table T4. Different levels of maturity in information handling.

B. Scope

B1. Business requirements

Level 1	Sustainability management is not part of business requirements.
Level 2	Sustainability management is part of business requirements but not fully integrated across all projects.
Level 3	The project management team monitors project activities to ensure that sustainability issues are addressed as it is an important business goal.
Level 4	There is full control and understanding of the business case for sustainability. Documentations are used as reference for upcoming projects. Top management is actively involved in developing the business requirements.

Table T5. Different levels of maturity in business requirements.

B2. Technical requirements

Level 1	Technical requirements for sustainability (i.e. measuring of carbon emissions, health and safety indicators etc.) are not specified.
Level 2	Technical requirements for sustainability are specified. For example, adoption of standards such as OHSAS and ISO14001.
Level 3	The project management team monitors and ensures that the standards adopted are met.
Level 4	Technical requirements are well-integrated across all projects. Benchmarking is in place to ensure that all relevant standards and best practices are adopted.

Table T6. Different levels of maturity in technical requirements.

B3. Deliverables

Level 1	Sustainability deliverables/goals are set in an ad hoc manner.
Level 2	A work breakdown structure (WBS) is in place to define processes that relate to sustainability goals. The structure in place is used as a communication tool to discuss the status of the project.
Level 3	Sustainability deliverables are monitored by the project management team. They are involved in developing and approving WBS.
Level 4	WBS is reviewed on a regular basis to identify areas for future improvement. Top management proactively ensures that sustainability deliverables are constantly met.

Table T7. Different levels of maturity in deliverables.

B4. Scope change

Level 1	Changes to sustainability scope happen quite frequently at different stages of the project.
Level 2	Changes to sustainability scope happen occasionally. The need for such changes is documented.
Level 3	The project management team monitors and recommends changes to sustainability scope only if required.
Level 4	Changes to sustainability scope are done only after consultation with stakeholders.

Table T8. Different levels of maturity in scope change.

C. Cost

C1. Project estimation

Level 1	No systematic process for estimating sustainability cost.
Level 2	There is a process in place for estimating sustainability cost.
Level 3	Sustainability cost is monitored by the project management team. They are involved in developing and approving the budget allocation in this area.
Level 4	Top management reviews sustainability cost and ensures that budget is not cut off for important programmes such as health and safety training.

Table T9. Different levels of maturity in project estimation.

D. Human Resource Management

D1. Resource planning

Level 1	There is no proper identification of resource requirements to manage sustainability.
Level 2	Resource requirements and sustainability expertise in projects have been identified.
Level 3	Resource planning is managed by project management team. Experts in sustainability are clearly identified and assigned to relevant projects to ensure the delivery of sustainability outcomes.
Level 4	Communication between different departments exists to identify gaps in resource planning. Top management is actively involved in resource planning.

Table T10. Different levels of maturity in resource planning.

D2. Recruitment process

Level 1	Recruitment of sustainability professionals done in an ad hoc manner. No clear competencies outlined.
Level 2	There is a written job description for sustainability skills required for the project.
Level 3	The project management team ensures there is a right mix of sustainability experts in projects.
Level 4	Top management is actively involved in reviewing sustainability job descriptions with human resources and sits in the recruitment process.

Table T11. Different levels of maturity in recruitment process.

E. Communication

E1. Planning in communication

Level 1	No planning involved in sustainability communication. Done in an ad hoc manner when the project management team feels appropriate.
Level 2	There is some evidence of a documented plan or milestone in communication of sustainability goals.
Level 3	Project management team manages the communication plan to ensure that stakeholders receive material sustainability information in a timely manner.
Level 4	Top management plays an active role in planning the communication process across all projects. This includes identifying the different channels of sustainability communication (media, sustainability reports, forums, annual meetings) and the timeline as to when such information will be disclosed to stakeholders.

Table T12. Different levels of maturity in planning for communication.

E2. Sustainability reporting

Level 1	Sustainability reporting primarily to fulfil basic requirements rather than with an intention to identify gaps for improvement.
Level 2	There is clear definition and agreed format for sustainability reporting.
Level 3	Project management team manages sustainability reporting. Similar criteria are reported for different projects to allow for comparability.
Level 4	There is evidence of a verification process in place to validate that what has been reported is indeed accurate and timely. Feedback from stakeholders is considered to continuously improve reporting standards.

Table T13. Different levels of maturity in sustainability reporting.

F. Procurement

F1. Procurement

Level 1	No evidence of incorporating sustainability thinking into procurement activities.
Level 2	There is a clear/documented process for considering sustainability issues in procurement.
Level 3	Project team manages and monitors the procurement process to ensure that sustainability goals are achieved.
Level 4	Top management plays an active role in ensuring that procurement is done in a socially responsible manner. Procurement policies are reviewed regularly to address deficiencies.

Table T14. Different levels of maturity in procurement.

F2. Contract management

Level 1	There are no contract clauses to ensure that sustainability goals are achieved.
Level 2	Contract terms and conditions are spelled out with possible penalties for unsatisfactory sustainability performance.
Level 3	There is a process in place for contract filing. A complete set of indexed records are managed by the project management team.
Level 4	Audits are carried out regularly in relation to sustainability-related contract clauses. This is to identify successes and failures. Future projects use this information to improve on current contract processes.

Table T15. Different levels of maturity in contract management.