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Ph.D. Thesis

Environmental Sustainability in Supply Chains: Evidence from the Construction Industry in the UK and Greece

This thesis is submitted for the degree of Doctorate of Philosophy (Ph.D.)

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ABSTRACT

Climate change, which has intensified over time, and its effects on humanity and the planet, have forced the governments of many countries to react in response to intense criticism from various socio-political actors, and to scrutinise and act on the problem. The academic community could not be absent from this move either, which, through thorough and coordinated research, is making every effort to reduce and mitigate the effects of this change. The main cause of climate change lies in the activities of companies that make the greatest contribution to the greenhouse effect. This thesis examines various factors that are relevant to the subject and strives to help confront the phenomenon. In the light of two theories, the Triple Bottom Line and Institutional Theory, examines the views of construction industry practitioners on the actions of their companies towards environmental sustainability practices. The reason for selecting the construction industry is due to its identification as the most polluting industry. To better understand the details and peculiarities of the industry, the level of coverage by the existing academic literature focusing on the UK construction industry was explored. The systematic review has shown that research so far, focuses mainly on energy issues of building installations and building materials and much less on issues related to the supply chain of companies. Based on the results of the systematic review and the bibliography of the green supply chain contributors, the author proceeded to conduct qualitative research to gather in-depth information on how businesses in the UK and Greece think and act. The interviews with 27 experts in the field have highlighted that the institutional pressures exerted on companies are classified as regulatory pressures, customer requirements, stakeholder pressures, external image or reputation, and competition pressures. These external pressures create internal responses to the adoption of sustainable environmental practices. According to the perceptions of the research participants, the key contributors to this direction are executive management support, financial factors, environmental management systems and the use of software in carbon footprint measurement, as well as education and training of organisation employees. The research completed with the case study of a Greek small-to-medium-sized construction company, where the use of a decision support system initially assessed the carbon footprint of the company and then investigated the feasibility of reducing it through interventions in the production process and its supply chain. This research provides a theoretical and practical contribution. The theoretical contribution is twofold. Initially, through the theoretical model it develops based on the institutional pressures on business, aiming at adopting sustainable environmental practices on their behalf. The second contribution is in the philosophical (phenomenological constructivism) and methodological (mixed purposive sampling) approach of the research, used for the first time in this research area. The practical contribution of the study is the highlighting of the intra-organisational factors that lead to the adoption of sustainable practices in the construction sector.

ΕΠΙΤΕΛΙΚΗ ΣΥΝΟΨΗ

Η κλιματική αλλαγή που εντείνεται με την πάροδο του χρόνου και οι επιδράσεις αυτής στην ανθρωπότητα και τον πλανήτη, ανάγκασαν τις κυβερνήσεις πολλών χωρών να αντιδράσουν κατόπιν της έντονης κριτικής διαφόρων κοινωνικο-πολιτικών φορέων και να ενσκήψουν πάνω στο πρόβλημα. Από την κίνηση αυτή δε θα μπορούσε να απουσιάσει και η ακαδημαική κοινότητα, η οποία με ενδελεχή και συντονισμένη έρευνα καταβάλει κάθε δυνατή προσπάθεια για να μειώσει και να περιορίσει τις επιδράσεις αυτής της κλιματικής αλλαγής. Η κύρια αιτία της εντοπίζεται στις δραστηριότητες των επιχειρήσεων που συμβάλουν τα μέγιστα στο φαινόμενο του θερμοκηπίου. Η παρούσα διατριβή εξετάζει διάφορους παράγοντες που άπτονται του θέματος και καταβάλει προσπάθεια ώστε να συνδράμει στην αντιμετώπιση του φαινομένου. Υπό το πρίσμα δύο θεωριών, Triple Bottom Line και Institutional Theory, εξετάζει τις απόψεις επαγγελματιών του κατασκευαστικού κλάδου ως προς τις ενέργειες των εταιρειών τους για να συμβάλουν σε πρακτικές περιβαλλοντικής βιωσιμότητας. Ο λόγος που επιλέχθηκε ο κατασκευαστικός κλάδος είναι διότι ο κλάδος αυτός χαρακτηρίζεται ως ο πλέον ρυπογόνος. Για την καλύτερη κατανόηση των λεπτομερειών και ιδιαιτεροτήτων του κλάδου, διερευνήθηκε το επίπεδο κάλυψης του θέματος από την υπάρχουσα ακαδημαική βιβλιογραφία που εστιάζει στον κατασκευαστικό κλάδο της Μεγάλης Βρετανίας. Η συστηματική ανάσκοπηση κατέδειξε ότι μέχρι σήμερα η ακαδημαική έρευνα εστιάζει κυρίως σε ενεργειακά θέματα των κτιριακών εγκαταστάσεων και οικοδομικών υλικών και πολύ λιγότερο σε θέματα που αφορούν στην εφοδιαστική αλυσίδα των εταιρειών. Βασιζόμενος στα αποτελέσματα της συστηματικής ανασκόπησης αλλά και στη γενικότερη βιβλιογραφία των συντελεστών πράσινων εφοδιαστικών αλυσίδων, ο συγγραφέας προχώρησε στη διενέργεια ποιοτικής έρευνας ώστε να συλλέξει εις βάθος πληροφορίες για τον τρόπο με τον οποίο σκέφτονται και ενεργούν οι επιχειρήσεις στη Μεγάλη Βρετανία και στην Ελλάδα. Οι συνεντεύξεις με εικοσιεπτά ειδικούς του χώρου, ανέδειξαν ότι οι θεσμικές πιέσεις που ασκούνται στις επιχειρήσεις κατηγοριοποιούνται ως ρυθμιστικές πιέσεις, απαιτήσεις των πελατών, πιέσεις ενδιαφερομένων μερών, εξωτερική εικόνα ή φήμη της εταιρείας και τέλος, οι πιέσεις από τον ανταγωνισμό. Οι εξωτερικές αυτές πιέσεις δημιουργούν εσωτερικές αντιδράσεις για την υιοθέτηση βιώσιμων περιβαλλοντικών πρακτικών. Σύμφωνα με τις αντιλήψεις των συμμετεχόντων στην έρευνα, οι βασικοί παράγοντες που συμβάλουν προς αυτήν την κατεύθυνση είναι η υποστήριξη της ανώτατης διοίκησης, οικομικοί παράγοντες, τα συστήματα περιβαλλοντικής διαχείρισης και η χρήση λογισμικού στην μέτρηση αποτυπώματος άνθρακα, καθώς και εκπαίδευση και κατάρτιση του προσωπικού των επιχειρήσεων. Η έρευνα ολοκληρώθηκε με τη μελέτη περίπτωσης μίας ελληνικής μικρομεσαίας κατασκευαστικής εταιρείας, όπου με την χρήση ενός συστήματος υποστήριξης λήψης αποφάσεων, διερευνήθηκε αρχικά η μέτρηση αποτυπώματος άνθρακα της εταιρείας και κατόπιν η εφικτότητα μείωσής του μέσω παρεμβάσεων στην παραγωγική διαδικασία αλλά και στην εφοδιαστική της αλυσίδα. Η παρούσα έρευνα παρέχει θεωρητική και πρακτική συνεισφορά. Η θεωρητική συμβολή είναι διτή. Αρχικά μέσω του θεωρητικού μοντέλου που αναπτύσει βασιζόμενο στις θεσμικές πιέσεις που ασκούνται στις επιχειρήσεις, στοχεύοντας στην υιοθέτηση βιώσιμων περιβαλλοντικών πρακτικών εκ μέρους των. Η δεύτερη συνεισφορά είναι στο χώρο της φιλοσοφικής (phenomenological constructivism) και μεθοδολογικής προσέγγισης (mixed purposive sampling) της έρευνας που χρησιμοποιείται για πρώτη φορά συνδιαστικά στο συγκεκριμένο ερευνητικό πεδίο. Η πρακτική συνεισφορά της έρευνας είναι η ανάδειξη των ενδο-επιχειρησιακών παραγόντων που οδηγούν στην υιοθέτηση βιώσιμων πρακτικών, στο χώρο του κατασκευαστικού κλάδου.

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List of Abbreviations

3BL	Triple bottom Line
BREEAM	Building Research Establishment Environmental Assessment Method
CIOB	The Chartered Institute of Buildings
CLCF	Centre for Low Carbon Futures
EAP	Environment Action Programme
EC	European Commission
ECAP	Environmental Compliance Assistance Programme
EEA	European Environment Agency
EMAS	Eco-Management and Audit Scheme
EMS	Environmental Management System
EU	European Union
GAP	Green Action Plan
GHG	Green House Gas
GSCM	Green Supply Chain Management
IEA	International Energy Agency
ISO	International Organization for Standardization
IT	Institutional Theory
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
NGO	Non-Governmental Organisations
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
SC	Supply Chain
SCEnAT	Supply Chain Environmental Analysis Tool
SCM	Supply Chain Management
SLR	Systematic literature Review
SME	Small and Medium Sized Enterprise
SSCM	Sustainable Supply Chain Management
TBL	Triple Bottom Line
UK	United Kingdom
UN	United nations

1 Introduction

1.1 Introduction of the Topic

A series of natural disasters has brought climate change to the fore in recent decades, starting in 1990 when global warming first became a point of international interest (Victor, 2013) and leading on to the Kyoto protocol which set targets related to the environment. A number of governments and organisations, understanding the scale of the challenge for humanity represented by climate change, made a commitment to reduce or eradicate its causes. Environmental impact is not restricted to climate change; other impacts include: the exhaustion of natural resources; restraints on land use; and the three related threats of acidification, toxicity and eutrophication. Be that as it may, climate change is the one that raises most concerns in relation to greenhouse gases (GHG). Almost 65% of GHG are carbon dioxide, which has been accepted as the main reason for climate change as represented by global warming (Brentrup *et al*., 2004). The warmest year for one hundred years combined with global disasters connected with the weather, caused NASA to begin research in 2005 with the objective of gaining control of the causes of global warming including GHG and, according to Lash and Wellington (2007), to reduce carbon emission levels by 60% by the year 2050.

The European Union has set a positive example by introducing policies calling for the use of forms of energy that are less polluting. EU policies also include environmental responsibility on the part of companies, cleaner transport, land use that is friendly towards the environment as well as other initiatives designed to reduce emissions of GHG (Europa, 2014). At the beginning, the strategy was intended to produce a 20% reduction in carbon emissions by 2020 on 1990 levels, but new targets have been introduced by the European Commission with their 2050 roadmap. The aim is now to achieve a reduction of 40% by 2030, 60% by 2040 and 80% by 2050 in transportation, generation of power, construction and agriculture.

As elsewhere in the world, the great majority of European businesses comprise small companies (Hillary, 2004). A significant proportion of the total impact on the environment comes from SMEs (Seiffert, 2008) and industries where most of the players are SMEs are now under pressure to improve environmental performance (Cordano et al., 2010). According to Bosselmann (2016) and Chaabane et al. (2012), increased concern about the environment has been backed up with legislation that forces companies to evaluate how their operations negatively affect the environment. Its supply chain is a significant attribute in an organisation's activities and how it seeks to reduce environmental impact and so, green supply chain management (GSCM) has assumed great importance (Diabat and Govindan, 2011). As well as reducing global warming by more intelligent performance, the introduction of GSCM makes for easier compliance with national and global environmental policies and legislation. It also improves the reputation of the brand and creates opportunities to add value and obtain competitive advantage (Kumar *et al*., 2012). It follows that green supply chain initiatives can benefit the company as well as the environment and society. Eltayeb et al. (2011) claim that the environment benefits from the production of products that are environmentally friendly, from recycling and reduced waste, and from better use of resources. The organisation is benefiting from improved efficiency of operations, reduced costs, and a better social image which leads to increased sales (Routroy, 2009). As companies come to understand both these benefits and the need for regulatory compliance, top management becomes concerned with environmental performance (Theyel, 2001). In addition, there are certificates of good environmental practice such as ISO 14001 (Bansal and Hunter, 2003). Environmental Management Systems (EMS) enable companies to take steps to reduce carbon dioxide emissions and to monitor their performance and become drivers for improvement throughout the supply chain (CLCF, 2011).

Managing the supply chain with the environment in mind, while simultaneously taking account of the need to integrate social and economic aspects, has placed emphasis on GSCM, but if environmental benefits and company profits are to be maximised while ensuring sustainable development, GSCM must be the subject of an approach that considers the product's whole life-cycle from product design, raw material selection and the manufacturing process right through to sales and recycling (Ondemir, 2012). In addition, companies must take on the challenge of measuring and controlling the carbon footprint right across the entire supply chain, since supply chains for any product are likely to involve processes in more than a single location (Sundarakani *et al*., 2010). Life Cycle Assessment therefore becomes the most useful approach in assessing a company's environmental impact measured by the totality of their effects including emissions of GHG (Chaabane *et al.*, 2012). The supply chain must be approached holistically and this is particularly true of construction, since that sector begins its life cycle with the extraction of raw materials and so is part of the problem of resource depletion before going on to pollute the environment right through to maintenance and waste disposal. Analysing the carbon footprint and measuring both direct and indirect GHG emissions requires that the process be considered by input/output analysis across the whole of the economy (Koh et al., 2013). Hybrid LCA is the answer if a complete understanding of all emissions resulting from a project is to be achieved (Finnveden *et al*., 2009).

Overall, there is lack of research in the construction industry's supply chains, relevant to sustainability (Tebaldi et al., 2018). Reviewing the relevant literature, the researcher identified several gaps that the current thesis aims to fulfil. First, there is lack of a systematic review of sustainable practices in the UK construction industry. The study of Myers (2005) examined the sustainability involvement of construction companies listed in the London stock exchange market, but was based on public disclosures of those organisations. The other two studies encompassing systematic reviews by Darko et al. (2017) and Darko and Chan (2016) are observing green buildings and have a global focus, including UK. The second gap refers to the development of a framework based on qualitative research, in either UK or Greek construction industry. The influence of institutional pressures on the construction industry have been investigated in other countries using qualitative and/or quantitative methods, but not in UK nor Greece. Finally, the application of the Supply Chain Environmental Analysis Tool to assess the carbon footprint of a Greek construction company has not been reported in the literature.

The aforementioned discussion comprises the factors which motivated the researcher to engage with the topic.

1.2 Research aims and objectives – Research questions

The aim of this study is to advance the knowledge and know-how of environmental sustainability consciousness and adoption by making theoretical and practical contributions in the construction industry, which is considered the highest pollutant among all other sectors of the economy. The objectives are; first, to investigate the extent to which sustainability issues in the UK construction industry have been researched and the areas of focus. Second, to investigate the drivers of sustainable practices among UK and Greek construction companies' supply chains; and third, to examine the suitability of a tool in assessing the carbon footprint of a construction company's supply chain.

In order to meet the aim and objectives of the study, four research questions were developed based on the review of the extant literature and trying to fill in the gaps found.

- **RQ1:** What is the breadth and depth of the environmental sustainability coverage in the UK construction industry by academia since the inception period of the sustainable construction guidelines?

- **RQ2:** What are the perceptions of construction managers, in both UK and Greek construction organisations, in terms of the drivers leading to the adoption of sustainable practices in their organisations and their supply chains, and how are these perceptions constructed?
- **RQ3:** How relevant is Institutional Theory in the context of sustainability drivers within construction industry's supply chains?
- **RQ4:** Does the application of a carbon assessment tool in a Greek SME construction company measure its carbon footprint and allow for interventions to lowering emissions?

Tackling the first research question, a systematic literature review was deemed appropriate. Oppenheim (2008) stated that the Scopus bibliographic database has the highest coverage of journals in the area of social sciences. Twenty databases were searched over a period spanning from January 1994 to August 2018, and the author performed inductive content analysis, based on the articles returned by the search, to reach at the conclusions .

The second and third research questions are answered following a qualitative approach by conducting twenty-seven interviews with construction professionals, thirteen from UK and fourteen from Greece, who have influential power within their organisations in decision making regarding environmental practices.

For the fourth research question, a case-study research design applying mixed methods has been undertaken. The SCEnAT was used to assess carbon emissions of asphalt production and two alternative scenarios were tested and evaluated in an effort to lower the company's greenhouse gas emissions.

1.3 Structure of the thesis

The thesis consists of the following seven chapters:

- Chapter 1 – Introduction

This chapter introduces the reader to the main concepts that are an integral part of the research, such as climate change and Greenhouse Gases (GHG), green supply chain management (GSCM), Environmental Management Systems (EMS), Life Cycle Assessment (LCA), and EU environmental policies. The aim and objectives of the thesis are also presented here, followed by the approach taken in each case in answering the respective research question(s).

- Chapter 2 – Theoretical Background

The second chapter provides detailed critical discussions on the main themes of the thesis and sets up the theoretical umbrella under which the research has been conducted. The Institutional Theory (IT) and the Triple Bottom Line (TBL) framework are the two theories setting the context of this research. Existing literature is critically reviewed in the aforementioned concepts and in sustainable construction. The chapter concludes with a review of the SCEnAT tool.

- Chapter 3 – Research Methodology

This chapter details the three different research designs in answering the research questions. For the first research question, desk research is conducted for the systematic literature review, using the PRISMA methodology and the reporting process adheres to the principles proposed by Boland et al. (2017). For the second and third research questions, the researcher incorporated a mixed purposive sampling method, combining snowball and homogeneous sampling techniques for conducting the interviews. A step by step explanation is provided for the analysis of the data using the NVivo qualitative data analysis software. The fourth research question is answered by conducting a case study research approach and utilising the SCEnAT software.

- Chapter 4 – Systematic Literature Review of Environmental Sustainability in UK Construction Industry

This chapter presents the results of the Systematic Literature Review and provides a critical analysis of the findings with regards to the level of coverage of environmental sustainability issues in the UK construction industry.

- Chapter 5 - Perceptions on Drivers of Environmentally Sustainable Supply Chains in the Construction Industry

The aim of this chapter is to present the findings of the qualitative research, to provide a thematic content analysis, and based on this analysis to develop a theoretical framework of adopting environmental sustainability practices. In doing so, numerous excerpts from the interviews are presented, so that the "voice" of the participants is heard. Throughout the presentation of this chapter, the discussion of the findings is linked with existing literature and the findings of previous studies on the topic.

- Chapter 6 – Case study: Assessment of Carbon Emissions and Interventions

This chapter presents the case study research design. The carbon emissions of a Greek construction company are assessed by using the SCEnAT software and then two different

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Figure 1.1*:* Structure of the Thesis

scenarios are also assessed in terms of their emissions. The results show that interventions on the supply chain processes are capable of lowering total carbon emissions.

- Chapter 7 – Conclusion and Recommendations

This final chapter provides a synopsis of the research outcomes and outlines the theoretical and managerial implications of the study. The chapter concludes with recommendations for further research and limitations of the current research.

- Reference List and Appendices

There are eleven appendices complementing the chapters of the thesis.

2 Theoretical Background

2.1 Introduction

This chapter sets the theoretical background of the thesis. The starting point is a discussion on the theoretical underpinnings of this research which is based on two main theories, the Triple Bottom Line and the Institutional Theory. Within their context, the researcher critically reviews the fundamentals of Supply Chains, Supply Chain Management, and Green Supply Chain Management as they relate to the sustainability principle and reviews sustainability challenges in the construction industry supply chains. The discussion continues with a review of environmental policies and legislation of the European Union and the compliance of UK and Greece, followed by a critical review of Environmental Management Systems and introduces the reader into the Life Cycle Assessment methods. The chapter concludes with an overview of the Supply Chain Environmental Analysis Tool, which is applied in the empirical part of the thesis.

2.2 The Triple Bottom Line Framework (TBL or 3BL)

The idea at the heart of sustainability is to meet present needs while at the same time leaving to future generations a world that will meet theirs, too. Sustainability has three dimensions, the environmental, social and economic (3BL), also known as the 3Ps (profit, planet, people).

An organisation's productivity, liquidity and profitability can all be affected by supply chain management (Johnson and Templar, 2011). A company's economic performance, which influences both its sustainability and returns for its shareholders, can be measured by labour cost and on-time product delivery free from defect both from suppliers and to customers (Halldorsson et al., 2009).

Sustainability's environmental dimension has to do with how a company uses natural resources to produce and deliver services and products. This includes recycling and reuse of products in a way that minimises carbon emissions harmful to the environment (Carter and Easton, 2011).

The third and final dimension, a sustainable supply chain's social performance, according to the Centre for Low Carbon Futures (CLCF) (2011) has to do with numbers of jobs created, spending on projects with focus on social responsibility, and the amount of training and quality of the jobs performed by employees with regard to acceptance of social responsibility.

Fischer et al. (2018) emphasise that sustainability demands a simultaneous focus on all three dimensions since focusing on each separately can expose the firm to risk and make it more difficult to achieve competitive advantage. Companies that are to combine all three dimensions may be able to improve their processes or even develop new ones to achieve competitive advantage that competitors may find it difficult to duplicate (Porter and Kramer, 2006; Saha and Darnton, 2005; Zutshi and Sohal, 2004).

With that in mind, Fischer et al. (2018) pointed to the considerable challenge of integrating the three 3BL dimensions. Trust, a close interaction between all engaged organisations (Gold et al., 2010) and choosing to be proactive and not reactive in the matter of sustainability (Hanim et al., 2012; Ramanathan et al., 2010; Baumgartner and Ebner, 2010), can make the difference in how products and services are seen and can reduce the risks inherent in implementation.

Integrating sustainability into SCM is not easy and demands a holistic approach on the part of every supply chain member linked to upstream and downstream members' corporate strategy (Carter and Rogers, 2008). It is necessary to integrate all three dimensions, at the same time examining how they interconnect when improvement or deterioration is seen in any dimension. Companies that realise sustainable supply chain management's importance will themselves be important in the development of a low carbon economy (Koh, 2013) which will benefit every partner in the supply chain. Sustainability can be the driver for improvement in bottom line performance, can contribute to sustainable development (Kauppi, 2013; Chu et al., 2017) and can create competitive advantage that competitors may find difficult to follow (Chang et al., 2017; Gopalakrishnan et al., 2012; Porter and Kramer, 2006).

2.2.1 Challenges in attaining sustainability

Turbulent business environments challenge operators and lead companies to follow accepted strategies for global supply chain, according to Sarkis et al. (2011), including lean, agile methods in order to handle fluctuating demand and achieve waste reductions, while, as Mangan et al. (2011) state, increasing service levels to customers. All of these approaches as well as decisions on the location of production and distribution facilities, transportation methods and supplier selection can have an impact on the whole supply chain's environmental success (Benjaafar et al., 2013; Halldorsson et al., 2009), including carbon emissions. Nor is that list of decisions exclusive. Given that the greatest percentage of firms operating all over the world are SMEs (Moore and Manring, 2009) and that sustainability is viewed differently country by country and industry by industry (Halldorsson et al., 2009), the number of factors that can influence success in sustainable strategy implementation is large, because many SMEs possess neither the resources nor the capabilities to implement sustainable strategies.

Regulatory pressure can come from governments (Yin et al., 2018; Singh and Gupta, 2014; Hanim et al., 2012; Dubey et al., 2015; Zhu and Sarkis, 2006) or from other stakeholders that may include NGOs (non-governmental organisations) and regulatory bodies (Saeed et al., 2018; Silvestre et al., 2018; Dubey et al., 2015; Kauppi, 2013). The pressure can also result from customer demand (Pitt et al., 2009; Abidin and Pasquire, 2005; Mudgal et al., 2010; Silvestre et al., 2018; Huang, 2012). These sources of pressure are regarded as the most important sustainability drivers, followed by pressures from the EU (Naidoo and Gasparatos, 2018; Silvestre et al., 2018; Hoejmose et al., 2012).

It has been emphasised by Seuring and Müller (2008a), however, that customer demand for sustainable products is lacking and, even where it exists, customers do not wish to pay extra for it (Wolf, 2011). By the same token Bai et al. (2012) point to increasing complexity (and therefore cost) in measuring supply chain performance because of competition as well as the range of measurements that can be applied (Hall et al., 2012). Cost therefore becomes a challenge for companies wishing to improve 3BL performance and can thus be thought of a great obstacle for organisations (Hojnik et al., 2018; Cai and Li, 2018; Chu et al., 2018; Shi et al., 2013; Tam et al., 2006). Establishing sustainable competitive advantage comes at a cost and requires investment.

Integrating 3BL demands a more holistic and proactive approach to reduce risks inherent in regulatory compliance. According to Winter and Knemeyer (2013), successful companies will obtain strong competitive advantage from the differentiation of their product, a view that is also supported by Vachon and Mao (2008) and Kleindofer et al. (2005). Initial costs of acting proactively though are high and cannot be ignored, thus, competitors hold that advantage (Kylili and Fokaides, 2017; Delai and Takahashi, 2013; Wu and Pagel, 2011; Al Khidir and Zailani, 2009). Nor is customer reluctance to pay more the only obstacle. Others include coordination and effective communication in the supply chain between suppliers, customers and the company (Arshinder et al., 2008; Patnayakuni et al., 2006; Simatupang et al., 2002), information being neither visible nor transparent between members of the supply chain (Marshall, et al., 2016; Stohl et al., 2016; Goswami et al., 2013), uncertainties about and changes in a state’s environmental policy (Kauppi, 2013; Silvestre et al., 2018; Roszkowska-Menkes and Aluchna (2017), the expectations of stakeholders concerning scarce natural resources and a low carbon economy (Yin et al., 2018; Lee and Kim, 2009; Vachon and Klassen, 2006), changes in technology that demand investment in information systems (Zutshi and Creed, 2015; Halldorson and Kovacs, 2010; Yiridoe and Marett, 2004) and – last but not least – the fact that human behaviour, according to Griskevicius et al. (2012), is influenced by what was done in the past and can prove resistant to change.

Be that as it may, companies can gain advantage by being the first user of an innovation, integrating sustainability into their operations, and developing effective collaboration (Etzion, 2007)) and this can lead to improvements in all three dimensions (Markley and Davis, 2007). A win-win among the three dimensions has been identified by a number of researchers (Fischer et al., 2018; Bosselmann, 2016; Arshinder et al., 2008), and research has shown strong supply chains to correlate positively with sustainability (Chaabane et al., 2011). Yakovleva et al. (2012) claims the result is long-term economic benefit and competitive advantage, which is a view being supported by other authors (Porter and Kramer, 2006; Saha and Darnton, 2005).

2.2.2 Misapprehensions of sustainability

Since the first appearance of the sustainable development concept, companies in many different industries have sought to make it part of their strategy, but in the present business environment sustainability and exactly what it means can be misunderstood (Balasubramanian and Shukla, 2017) .

According to Kauppi (2013), the environmental dimension has taken priority and there has been insufficient focus on the economic and social dimensions. On the other hand, according to Purvis et al. (2018), sustainability's economic dimension has been the subject of research much more often than the environmental and social dimensions, of which the social dimension is so far the least explored, especially in the construction industries supply chains (Chang et al., 2017; Balasubramanian and Shukla, 2017; Chu et al., 2017).

Hall et al. (2010) point to a gap in the literature concerning how entrepreneurship and sustainable development link. To achieve sustainability, it is essential to focus on all three dimensions (Barbier and Burgess, 2017; Barbier and Markandya, 2013), and failure to elucidate triple bottom-line integration means failing to measure sustainable performance throughout the supply chain, ignoring the requirement that all supply chain elements collaborate (Caradonna, 2014), and making it difficult to measure either social or environmental performance, as Hubbard (2009) claims. There has not been adequate research on managing a SSCM and on how the pillars of the Triple Bottom line are interconnected

(Caradonna, 2014), and on the need for supply chain performance to be measured as something more than the performance of a single company (Svensson, 2007).

2.3 Institutional Theory

Institutional Theory makes it possible to analyse the influence pressures can have on an organisation (Shubham et al., 2016) as well as providing the perspective to study such factors driving organisational practices' survival and legitimacy as rules and regulations, history, culture and economic incentives (Bruton, 2010; Baumol et al., 2009; Lai et al., 2006). By legitimacy is meant the sustainability practices that stakeholders consider appropriate (DiMaggio and Powell, 1983). Institutional Theory's concern has been how organisations secure their positions and legitimise themselves by working within rules that exert a pressure to conform within the environment in which they operate (DiMaggio and Powell, 1983; Meyer and Rowan, 1991; Scott, 2007). Organisations that achieve their goals are legitimised and society trusts them with resources (Toma et al., 2005).

The literature indicates a range of viewpoints concerning benefits Institutional Theory can confer. It has been used to show how social values change and to illustrate technological advance and regulation (Ball and Craig, 2010; Lounsbury, 1997), management of the environment (Glover et al., 2014 citing Brown et al., 2006), and sustainability in action. Delmas and Toffel (2004) used it as a way of studying strategies, which organisations have used to implement management of the environment.

Institutional Theory is not without its limitations, however. When researchers used it to describe how institutional diversity varied, it did not fully describe the empirical findings described in the literature (Morphew and Huisman, 2002; Morphew, 2009). Thus, Morphew and Huisman (2002) reported an assumption by the theory that laws and regulations have a coercive, one-way effect capable of increasing or decreasing institutional diversity inadvertently.

2.3.1 Drivers of Institutional Theory

Three forms of drivers are recognised in Institutional Theory: coercive, normative and mimetic isomorphism. This affects the way certain practices are implemented by organisations (DiMaggio and Powell, 1983; Shubham et al., 2016). Economic rationale is not always the reason for an organisation's decision (Shubham et al., 2016) and this tendency towards similarity is to be found in the structures and strategies of organisations and in their processes (DiMaggio and Powell, 1983).

At the root of coercive isomorphism is the influence of those in positions of power such as government. Coercive pressures ensure that environmental management is in full operation to achieve sustainability (Kilbourne et al., 2002), but sustainable management can be encouraged by methods other than government regulation. A significant role is also played by professional and industrial bodies. Alternatively named normative pressure, it persuades organisations to comply so that they can be seen as participators in legitimate actions (Sarkis et al., 2011). It is expected that industry members will comply with norms, rules and regulations the industrial associations create, which may include environmental standards designed to encourage companies to operate in a more environmentally responsible way. Ball and Craig (2010) reported that normative isomorphism produced greater levels of environmental consciousness in organisations. How organisations' respond to environmental problems and society's rules requires research. While self-regulation is encouraged by some governments, industries have preferred self-regulation through an association to government regulation that amounts to coercion (Campbell, 2007) and the purpose of normative drivers is to influence organisations to observe the social obligations they should be practising in any case (March and Olsen, 1989).

Mimetic drivers can be seen at work when a company copies competitors who are doing well in the hope that they will achieve the same level of success (Sarkis et al., 2011). According to Bansal (2005), organisations that imitate their main competitors are less prone to negative publicity, since activities may be legitimised when many organisations are doing the same thing.

To summarise, institutions can define what is legitimate and appropriate, causing other activities to be seen as unacceptable or not worthy of consideration (DiMaggio and Powell, 1991). In this way, organisations decide how to conform and how to meet regulatory and social pressures (Westphal et al., 1997).

2.3.1.1 Coercive Pressure

The operations of manufacturing companies have been governed by regulations on production processes, product specification and product performance (Anderson et al., 1999; Cairns, 2006). Manufacturing processes having to consider sustainability, according to newly established regulations, place more emphasis on the environmental pillar of the Triple Bottom

Line framework. The construction industry has been impacted by environmental regulations including EU Directives, such as Energy Performance of Buildings, EU Landfill Directive, Hazardous Waste Regulations, Control of Pollution Regulations, Site Waste Management Plans Regulations, Energy Performance Certificates, Carbon Reduction Commitment Energy Efficiency Scheme, among others (CIOB, n.d.). Similarly, manufacturing has become increasingly complex as it seeks to comply with the differing regulations in different geographical locations, but according to Shubham et al. (2016), manufacturers comply with such regulatory pressures by engaging with more environmentally friendly practices. In fact, according to Bey et al. (2013), companies stay in touch with preliminary discussion of possible new regulation in order to ensure that they continue to be compliant.

Delmas and Toffel (2004) found coercive pressures to be effective, with government regulations stimulating organisations to adopt sustainable practices. They based this on organisations' adoption of EMS as a result of their wish to improve their legitimacy and their relationship with the most significant institutions. Darnall and Sides (2008) concurred, finding that EMS adoption correlated positively with coercive isomorphic pressure. In similar vein, Sangle (2010) found similar results in India where the strongest influence to adopt an environmental strategy was pressure from institutions.

The same result has been found in a study on China, where state regulations resulting from globalisation have been found to be the most important driver of green supply chain manufacturing practice (Zhu and Sarkis, 2004). Wu et al. (2012) found the Taiwanese government's initiatives to reduce pollution and improve technology in the textile and apparel industries to have been the reasons behind organisations' environmental practice implementation.

2.3.1.2 Normative Pressure

Industry associations bring pressure on construction and manufacturing companies in such very polluting industries as petrochemicals, chemicals, metallurgy and nuclear energy. The pressures in question acted as industry self-regulation and opposing organisations were discredited (Hoffman, 1999; Bingeman et al., 2004). While manufacturing industry's legitimacy and credibility have sometimes been damaged by environmental and social irresponsibility, the number of incidents is small (Tate et al., 2011), leading industrial associations to develop environmental standards of their own so that member organisations would be protected against the steady increase in external regulation. The International

Council of Chemical Associations, for example, encouraged environmentally sustainable behaviour by introducing "Responsible Care", an initiative to improve dissemination of information about risks and management of chemicals in the supply chain. In all, 536 chemical manufacturing firms committed to improve environmental and social performance (King and Lenox, 2000).

Empirical evidence exists that, in developed economies, trade associations and buyers bring pressure on companies, who may signal their commitment to a sustainable environment by signing up to an EMS (Qi et al., 2011). According to that research, industrial customers would prefer doing business with firms visibly practising sustainability. In this way, international trade associations and buyers bring normative pressure that acts as a driver for the adoption of sustainability practices in manufacturing processes. Corporate image has also been touted as a primary driver for waste recycling by Japanese manufacturers in preference to regulation and other coercive pressures (Zhu et al., 2010). This may be because in Japan the law was already well established.

Shubham et al. (2016) state that norms and standards concerning one manufacturer in an industry's professional network may influence another organisation in the same network, leading to pressure from the host organisation on their manufacturing and supply partners to also adopt sustainable manufacturing practice. In the developing countries of the southern and South-eastern region of Asia, self-regulation is increasingly important as a source of pressure for adoption of control standards on industrial pollution by manufacturing plants (Hettige et al., 1996). The same study found coercive pressures in this region to be weak. Trade associations in export destinations also applied normative pressures and were significant in encouraging sustainable manufacturing practice in major textile exporters like Bangladesh, Cambodia, China and India (Prakash and Potoski, 2006). Chiarini (2014) also mentioned the importance of self-regulation, with companies certified under the Environmental Management System ISO 14001 being required to publish an annual environmental balance and policy report to show their environmental strategy investment.

2.3.1.3 Mimetic Pressure

Uncertainty exists about sustainable management practices' value and effectiveness (Bansal, 2005) and this has led to organisations imitating other organisations that had established legitimacy through sustainability practices. This is in line with the conclusion that companies sought positive coverage and a good reputation and were, therefore, willing to imitate role-model leaders (DiMaggio and Powell, 1983). For manufacturing companies, for example, benchmarking is a way to improve production processes by copying the competition (Yakovleva et al., 2012; Voss et al., 1997). Japanese manufacturers, according to Shubham et al. (2016), adopted mimetic isomorphism in the 1990s for similar reasons. The same author also claimed that competitive pressures could lead manufacturing organisations to engage in environmental activities to avoid being undervalued compared with the competition. The adoption of EMS and ISO 14001 in particular by manufacturing companies, is due to competitive pressure and the risk of losing competitive advantage (Delmas and Toffel, 2004).

2.3.2 Internal and external pressures as sustainability constructs

By constructs of sustainability are meant drivers or other factors leading companies to follow sustainable practices. Pressure is a word seen frequently in the literature, and may be regarded as a general construct of sustainability. Pressure on companies to incorporate sustainable development in their projects and activities is increasing (Labuschagne and Brent, 2005). Organisations and industries may have a range of internal policies but they must make sure that economic growth is pursued in a way that benefits society and protects the environment. Sourcing raw materials and recruiting staff locally are examples, as is working with green suppliers. Companies owe a duty of care to society and there is constant pressure to keep operations in line with the three pillars of sustainability (Keeble, 2003). This three-way balance can be difficult to achieve as is shown by the construction industry in the UK where environmental sustainability takes precedence over the other two (Opoku and Ahmed, 2013).

Stakeholders, too, press companies to pay more attention to social rather than environmental sustainability, the social element being seen as generally the weakest of sustainable development's three pillars, according to Lehtonen (2004), thanks to its lack of an analytical and theoretical grounding. A research that studied pressures on companies to operate in a sustainable way, identified three main sources of pressure and classified them as management, internal and external factors (Gunasekaran and Spalanzani, 2012).

According to Law and Gunasekaran (2012), internal factors refer to such aspects of an organisation's operations as strategies for sustainable development and the organisation's policies, while the external ones include regulations and market demands. Sustainable development is also driven by real business incentives (Becker-Olsen, et al., 2006). For example, high-tech companies are under pressure from market requirements to manufacture sustainable products so that the organisation's reputation is improved, while others pointed to

European Union's regulations as a way that financial, legal and market pressures in Europe have promoted the manufacture of sustainable products (Maxwell and Van Der Vorst, 2003).

A company's strategy will typically be the result of management decisions, and so management attitudes towards sustainability are a key driver in the implementation of sustainable development strategies (Closs et al., 2008). Marz et al. (2003) agreed and found that leaders whose sense of guiding principles and shared values is strong are more likely to make changes for the better. Law and Gunasekaran (2012) found the value as a sustainable development motivating factor was higher for management and internal factors than external factors. According to Schrettle et al. (2014), sustainability's global emergence as a major challenge significantly impacts on organisations' decision-making and means that relevant decisions are regarded as strategic. The same authors report that decisions on sustainability may often be ad-hoc in nature, and this as it relates to project management has also been studied by Hepworth et al. (2017).

The relationships between coercive, normative, and mimetic pressures with the internal, external, and managerial factors have been researched (Tachizawa et al., 2015). Society, suppliers, customers, banks and insurance companies all act as normative pressures, while competitors are mimetic pressures and anything to do with government or legislation is a coercive pressure. The major management and internal factors were not related to isomorphic pressures. Schrettle et al. (2014) provide a similar driver classification, though their work divided sustainability drivers into exogenous and endogenous drivers and they were not researching Institutional Theory.

2.4 Supply Chains

A successful business depends, among other things, on meeting customer requirements and fulfilling customer expectations (Banomyong and Supatn, 2004). A supply chain balances demand and supply (Christopher, 2005). It will embrace a range of businesses in the fields of obtaining raw materials, manufacturing the product and distributing it (Beamon, 1998). According to La Londe and Masters (1994), the supply chain should be regarded as a group of companies all involved in the transformation and onward transmission of materials until they arrive with the end user, while in the view of Thomas and Griffin (1996), there are three stages to a supply chain: procurement, production and distribution. Akkermans *et al*. (2003) point to three flows that are central to the supply chain: material flow; information flow; and resource flow.

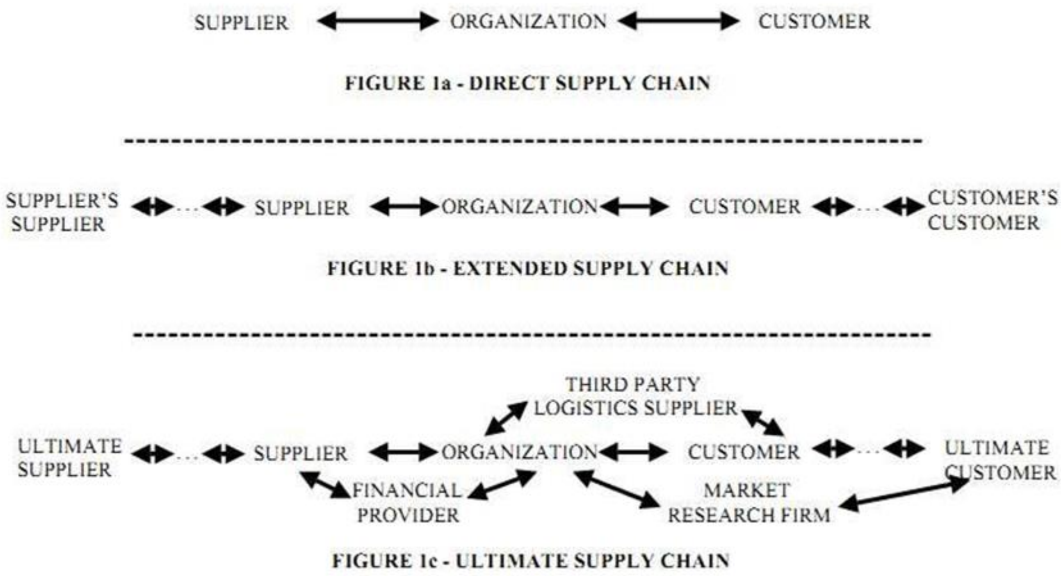


Figure 2.1: Direct, Extended, and Ultimate Supply Chains

Source: Mentzer *et al*. (2001)

The definition of a supply chain given by Mentzer *et al*. (2001) is:
"[…] *a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer*." (Mentzer *et al*., 2001; p. 4)
The authors go on to say that, supply chains come in three types: direct, extended, and ultimate. These are shown in figure 2.1. They also draw attention to the fact that there is a difference between a supply chain and supply chain management; the first is simply something that can be said to exist, while the second requires management action by every entity in it (Mentzer *et al*., 2001).

2.4.1 Supply Chain Management

The expression Supply Chain Management (SCM) first appears in the literature in a paper by Oliver and Weber (1982) and has since been the subject of considerable interest both on the part of academics and of supply chain professionals. The volume of publications on SCM has been increasing particularly since the mid-1990s, helped by advances in IT and market globalisation that drew increasing attention to the need to integrate and manage processes right across the supply chain (Stock and Boyer, 2009). Kopczak and Johnson (2003) see SCM as addressing challenges faced by today's businesses in a complex and uncertain world and as being something much greater than merely fulfilling orders. According to Lambert and Cooper (2000), SCM's objective of value generation is not restricted to one company but affects every member of the supply chain and the end customers. Christopher (2005) has examined current developments and reports that supply chains today are where competition is fiercest and company advantage to be gained.

Gibson *et al*. (2005), however, point out that no agreement has been reached on the definition of SCM and that the degree to which SCM has been investigated varies between industries. Agriculture, for example, has not had a great deal of research and descriptions in the literature of SCM in the agricultural sector are fairly new (Bhagat and Dhar, 2011). Shukla and Jharkharia (2013), having reviewed the literature for the past twenty years, say that while SCM has broadened in scope during that time, manufacturing and services are still the sectors most researched and agri-food fresh products the least.

According to Beamon (1999), current research into the supply chain from initial transformation of raw material through production of finished goods to their delivery to customers is revealing much greater complexity than heretofore. According to the same study, environmental impact is becoming increasingly important in the measurement of a supply chain's efficiency and effectiveness, which was previously more concerned with satisfying the customer while reducing costs.

2.4.2 Green Supply Chain Management (GSCM)

Supply chains as we know them, are defined as linear in nature (Mentzer et al., 2001); they rely on a continuing source of raw material and on the environment having an unlimited capacity to absorb waste including the hazardous material to which manufacturing can give rise (Geyer and Jackson, 2004). Environmental concerns, both locally and globally, are now such that businesses around the world face the challenge of marrying industrial growth with protection of the environment (Beamon, 1999; Eltayeb *et al*., 2011). In the opinion of Fiksel (1996), there is acceptance of the idea that it is production and manufacturing that provide the main threats to protection of the environment because of the waste they create, the natural resources they exhaust, and the ecosystem they disrupt. It follows that, as an inseparable part of the business, the supply chain must play its part in increasing awareness of environmental issues and GSCM is seen as the way to achieve this (Shi et al., 2012).

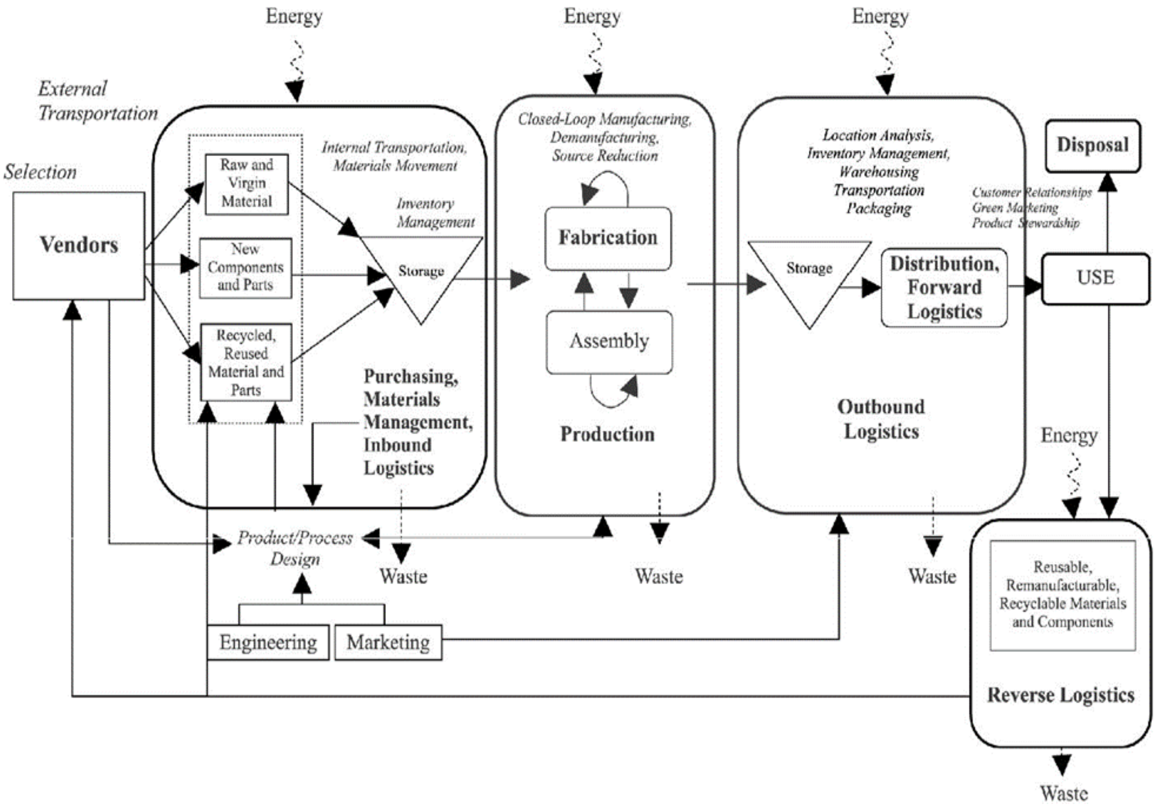


Figure 2.2: Closed-loop GSCM scheme

Source: Hervani et al. (2005)

According to Hervani et al. (2005), GSCM's objective is the reduction or even complete elimination of such negative environmental impacts as water pollution, air pollution, and land pollution as well as the wasteful use of resources whether energy, raw materials or products. The aim is to establish a "closed loop" embracing the whole cycle from raw material acquisition through manufacturing to disposal and recycling. This is shown in figure 2.2.

Srivastava (2007) brought together GSCM literature and outlines a number of supply chain stages where it is possible to add "green" practices: design, sourcing, operations, manufacturing, distribution, reverse logistics and waste management. Sarkis et al. (2011, p. 3) defined GSCM as: "[…] *integrating environmental concerns into the inter-organizational practices of SCM including reverse logistics*".

2.4.3 Rationale for embracing Green Supply Chain Management

Apart from the environmental contribution, the benefit from GSCM initiatives in both economic and social terms and a contribution to achievement of the "triple bottom line" that marks a society's sustainable development are powerful motivators (Eltayeb et al., 2011).

Nevertheless, and despite the fact that confirmation exists in a number of studies of the link between GSCM and companies' economic performance in addition to environmental benefit (Zhu and Sarkis, 2004; Rao and Holt 2005), other studies have found no such significant relationship (Vachon and Klassen, 2006; Zhu et al., 2007). Be that as it may, when Bose and Pal (2012) analysed announcements by listed companies of 104 GSCM initiatives, they found the effect of the announcements on the companies' stock price to be highly positive.

In addition, Kumar et al. (2012) drew attention to the following motivating factors for adopting GSCM: global warming; compliance with legislation and regulation; the awareness of stakeholders; the reputation of the brand; the prices of energy and commodities; the creation of value; development of competitive advantage; and more integrated and better managed supply chains. The study divided those motivating factors into two groups: internal drivers and external drivers.

While is true that the position a company holds in the market will be affected by its customers' awareness of green products and how they evaluate the company's environmental performance (Doonan et al., 2005), the greatest influence on business comes from internationally operative environmental regulations and the environmental legislation and policies of the business's local government (Chien and Shih, 2007). Diabat and Govindan (2011) investigated factors driving GSCM implementation and found legislation and government regulation to be the most powerful drivers leading to the reduction and elimination by business of its impacts on the environment. Holt and Ghobadian (2009), in a study of 60 UK manufacturing companies, came to the same conclusions, with pressure from society and individual customers having the least effect while the most powerful effect came from legislation and internal company pressures.

Routroy (2009) analysed what precedes the implementation of GSCM in manufacturing and found two factors: commitment on the part of top management, and initiatives from governments. That study found the commitment of top management to be the first and most important factor, with initiatives from government coming second, though the author made it clear that the importance of government initiatives should not be underestimated.

For all that, GSCM tends to be seen as unrewarding and as something of which the fundamental impact is to increase production costs. The aspects of GSCM that lead to this conclusion are its complexity, the surrounding regulations, customer pressures, and costs (Hsu and Hu, 2008). Sarkis (2003) presented the contrary argument that, while short-term costs could be high, long term benefits were considerably greater and, in the end, reduced the company's overall costs while Srivastava (2007) reported that GSCM implementation does reduce the impact on the environment without necessarily sacrificing product reliability and quality or energy efficiency and without necessarily increasing costs. This view was borne out when Mallidis et al., (2012) conducted a case study of a South-Eastern Europe supply chain and found that, by adoption of CO_2 emission reduction policies, companies could reach a fair balance between costs and environmental efficiency.

The general consensus is with Sarkis et al. (2011) and holds that GSCM is subject to growing attention in both the academic and the business worlds. This is expected to become even truer with the passage of time. It is possible to argue that the evolution of GSCM happened separately from other factors and Sarkis (2012) points to a number of philosophies concerning the environment which had supported GSCM. Study areas with close links to GSCM include: eco-design, industrial ecology, EMS, product stewardship, and LCA (Geyer and Jackson, 2004). Environmentally sustainable practices connected to green supply chain management together with the links to Environmental Management Systems and Life Cycle Analysis (see sections 2.6 and 2.7, respectively) are shown in figure 2.3.

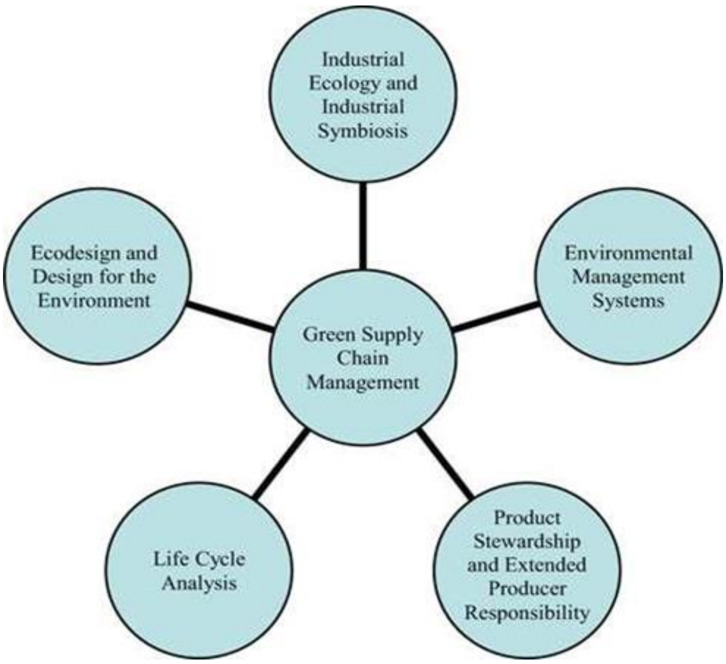


Figure 2.3: Environmental practices of industries

Source: Sarkis (2012)

2.5 Sustainability in construction industry supply chains

Reports that the construction industry is a heavy consumer of energy and produces large amounts of waste, some of which is hazardous, are frequent in the literature (Heravi *et al*., 2015b). It is an industry that spends very large amounts not only on the cost of completing a project but also on material procurement, maintenance and demolition; it is also an industry that satisfies basic physical and social needs by providing accommodation and infrastructure and, as a result, stimulates economic activity and generates considerable economic returns (Durdyev et al., 2018). The industry in UK employs nearly 1.4 million people (Office for National Statistics UK, 2018). It has a negative environmental effect through land and water use, emission of greenhouse gases, and consumption of resources including timber and non-renewable materials (Opoku and Ahmed 2013; Durdyev et al., 2018). According to the Department for Business Innovation and Skills, (BIS, 2010; p. 3), "***the amount of CO2 emissions that construction can influence is significant, accounting for almost 47% of total CO2 emissions of the UK***". Figure 2.4 shows the emissions by the industry from 1990 to 2016.

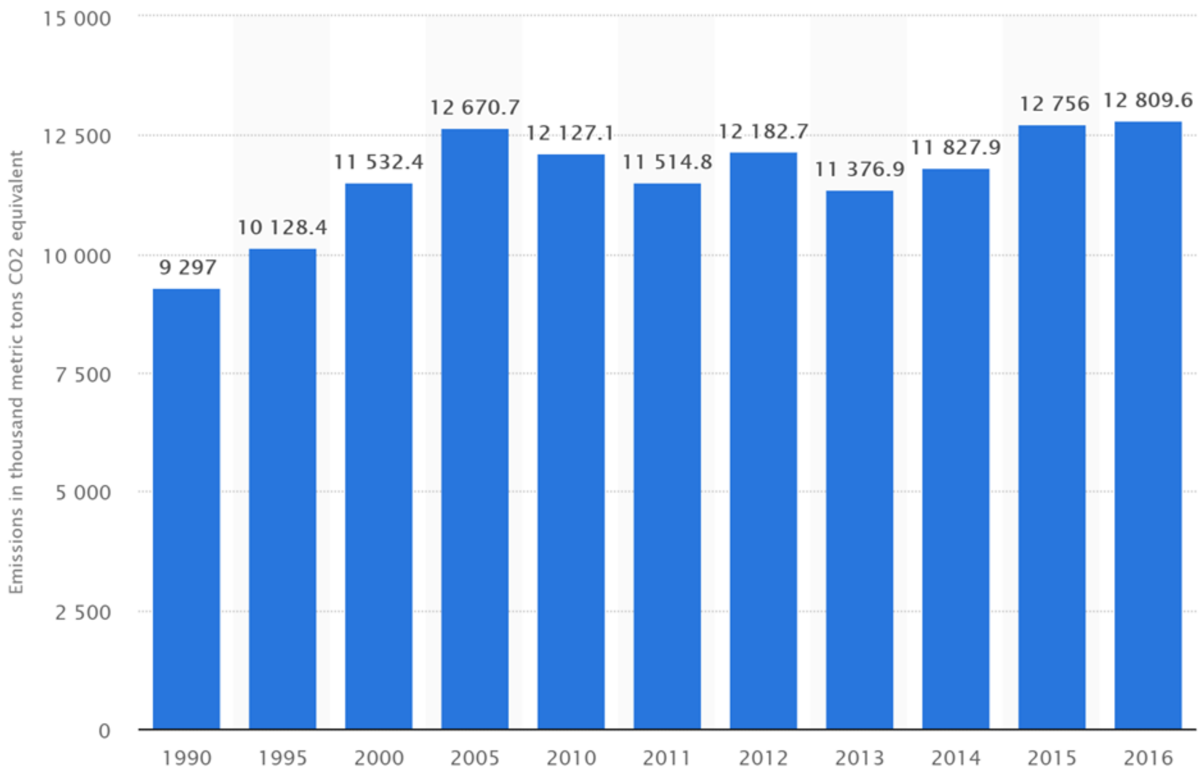


Figure 2.4: UK construction industry's GHG emissions (thousands of tons of CO_2 equiv.)

Source:www.statista.com/statistics/485911/greenhouse-gas-emission-from-the-construction-industry-uk/

The issue escalates even further when we take into consideration the growth of the construction industry in UK. In Europe, and specifically in the EU-19 (euro-area, countries that have adopted the euro currency), the industry came across a significant growth decline since the beginning of the global economic crisis in 2008, but started picking up again from 2013 up to date (Office for National Statistics, 2018). Figure 2.5 demonstrates those trends and shows that UK and Germany have the greatest recovery growth. According to the report, the construction industries of Italy and Greece had a significant negative impact in the decline of the EU-19 statistics.

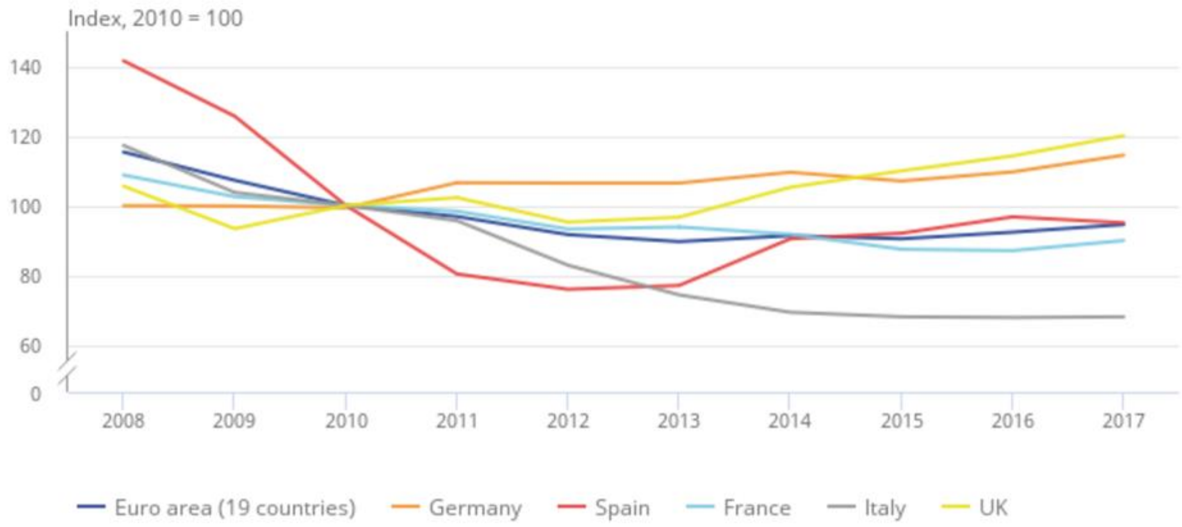


Figure 2.5: Volume growth of the UK construction industry

Source: Eurostat (2018)

Thus, the necessity for construction to be sustainable has been the focal issue of a great deal of work. The concept of "sustainable construction" was put forward by Fernandez-Sanchez and Rodriguez-Lopez (2010), where it focused on buildings, but since then it has been embraced by the entire civil engineering sector. It was defined by Khalfan (2006) as a process incorporating TBL (triple bottom line) to produce sustainable outcomes through accepting the need for a responsible approach to the environment, awareness of social issues, and to be economically profitable in relation to the environment and not just the project at hand. Durdyev et al. (2018) endorsed this idea by describing SC as holistic and as harmonising and creating balance between society, the economy and the environment. Sustainable construction has also been described without emphasising TBL, mainly by approaching the concept through its environmental dimension. In other cases, the social and environmental impacts have been emphasised, as have the development of an environment built with health in mind through efficient natural resource use to produce buildings that save on energy and protect residents' health and well-being (Dobrovolskiiene and Tamosiuniene 2016). SC generally includes sustainable development with the aim of reducing the environmental impact of construction, ensuring the comfort and safety of users of the building and, at the same time, increasing the building's economic value (Opoku and Ahmed 2013).

Edum-Fotwe and Price (2009) studying sustainable construction, claim that it was sustainability's environmental aspect to which the construction industry paid most attention. By the environmental aspect is meant managing natural and physical resources and conserving them for the future, according to Renukappa et al. (2012). The literature has many requests for natural resources to be used efficiently in construction. According to Dyllick and Hockerts (2002), construction can only be regarded as environmentally sustainable when natural resources are consumed more slowly than the rate at which they are reproduced, when emissions are lower than the rate at which they can be absorbed by the natural system, and when the industry disengages from activities that degrade the ecosystem.

The shift to address sustainability from a social-economic view, and away from an environmental view, was discussed by Edum-Fotwe & Price (2009). They looked at sustainable development's social dimension within the construction industry and proposed a model/framework that combines economic, social and environmental aspects.

2.5.1 Challenges of sustainability in the construction industry

Effective sustainable construction implementation has been described as requiring all aspects of TBL to be covered uniformly (Sev 2009). Renukappa *et al*. (2012), however, report the absence of collaborative definitions of sustainability within the industry and of its supply-chain objectives, which challenges understanding and implementation of the initiatives. This absence was said to be standard in the construction sector with the result that there was no common, operational understanding of what sustainability actually means.

It is also true that practising sustainability in the construction sector is highly complex. Hoffman & Henn (2008) analysed barriers in the way of green building, or sustainable construction. They reported barriers both psychological and social between individuals, within and between organisations, and at institutional level. At the individual level, decisions were influenced by factors including too high a discount on the future, “positive illusions,” assumption that the pie was fixed in size, and levels of environmental literacy. At the organisational level, the influences came from the internal culture, language, the reward system, and simple inertia in the organisation (Hoffman & Henn, 2008). Defined boundaries, defined responsibilities and competing interests all depend on a pie that is assumed to be fixed to ignore sustainable construction implementation resulting in failure of the organisation to enjoy the benefits it could. Fear of the unknown is another reason for organisations to dislike change, with preferences for what has always been done even though what has always been done may not be sustainable over the longer term (Hoffman & Henn, 2008).

At the institutional level, three categories influence sustainable construction implementation: the regulative, the normative and the cognitive aspects. Regulative institutions are seen as sanctioning businesses to be sustainable while impeding innovation and not advancing the interests of society.

Normative institutions set out standards that get in the way of sustainability. Hoffman & Henn (2008) report that there are in the construction sector a number of organisations endorsing specific parameters for construction of buildings and for the training of future practitioners. Cognitive institutions represent powerful perceptions that resist change and have a strong indirect influence on both individuals and organisations.

Sustainability is so complex a concept that construction industry decision-makers face a range of barriers, among which is a lack of awareness of how best to achieve sustainable development (Garbie, 2015; Park and Ahn, 2012), amounting to a failure to know when – or where, or how –sustainability should be transformed into practice while retaining competitive advantage.

2.5.2 Contemporary focus of sustainable construction supply chain research

All aforementioned discussion on supply chains and specifically on green supply chains apply equally to the construction industry’s supply chains as well. According to the European Commission (n.d.), the construction industry faces four major challenges. First, to stimulate demand by improving the energy-efficiency and renovate existing buildings. Second, to make improvements in the way blue-collar personnel receive specialised training. Third, to improve the uptake-rate of new technologies in order to become more innovative. Fourth, to deal with energy-efficiency and climate change (European Commission, n.d.). It is evident from studying the current literature of sustainable supply chains in the construction industry that researchers worldwide are focusing on very specific areas during the current decade. The focus of this thesis is fully aligned with the contemporary research trend of the construction industry. As it can be seen in table 2-1, the issues receiving greater attention range among life cycle analysis in assessing and reducing carbon emissions caused by supply chain operation, green procurement (green suppliers), drivers and barriers of implementing green practices in the supply chains, reverse logistics, and strategies stemming from environmental policies and gaining competitive advantage through green innovations.

Table 2-1: Themes of contemporary research on Sustainable Supply Chains in the construction industry

Author(s)	Year of Publication	Research Theme	Country of Research
Balasubramanian and Shukla	2018	Theoretical underpinnings	UAE
Chileshe et al.	2018	Reverse logistics	Australia
Giannoni et al.	2018	Sustainable business strategies	Chili
Kono et al.	2018	Life Cycle assessment	Switzerland, Germany , Japan, Sweden, Thailand, USA
Trochu et al.	2018	Reverse logistics Network design Quality issues Environmental policy Uncertainty	Canada
Alwan et al.	2017	Waste and energy reduction	UK
Balasubramanian and Shukla	2017	Drivers and barriers	UAE
Bohari et al.	2017	Green procurement	Malaysia
Genovese et al.	2017	Circular economy and life cycle analysis	UK
Shen et al.	2017	Barriers to green procurement	China
Khaksar et al.	2016	Green suppliers, environmental performance, competitive advantage, green innovation	Iran
Nasir et al.	2016	Linear and circular supply chains	UK
Wong et al.	2016	Green procurement	Hong Kong
Bartolozzi et al.	2015	Life Cycle Assessment	Greece
Chun et al.	2015	Business Activities, Business strategies, Environmental regulation	Republic of Korea
Dadhich et al.	2014	LCA and GHG	UK
Shi et al.	2013	Critical factors, barriers	China
Park and Ahn	2012	Strategic Environmental Management	Republic of Korea
Hakkinen and Belloni	2011	Barriers and drivers	Finland

2.6 Environmental Policies of the European Union

2.6.1 Towards a sustainable green economy

International laws, such as those issued from United Nations, can be classified as "hard" or "soft laws". A country committing itself to an international treaty or protocol is bound to fully comply with the so called "hard law". On the hand, the "soft laws" are not mandatory or imposed on a state, rather they are issued to serve as recommendations. The United Nations (UN) convention on Climate Change in 1992 in New York led to the Kyoto protocol in 1997 and was signed by its one-hundred-ninety-five member-states committing to take actions in limiting the greenhouse effect (rising temperatures). There were two "commitment periods", the first from 2008 to 2012, and the second from 2013 and ending in 2020. This is an example of a "hard law" (CIOB, n.d.).

The classification of European Union's legislation comes under primary and secondary laws. The primary ones are powerful and become member-states' laws. The secondary legislation comes in the form of regulations, directives, and decisions. Regulations are overriding member-states' legislation, while directives need to be implemented in reaching their intended results, such as the environmental directives. Last, decisions concern a specific member or organisation (CIOB, n.d.).

For all the progress made in recent years in tackling the critical challenge of climate change, Europe still has a number of major environmental problems to deal with, but also opportunities to build a more resilient and robust environment. A self-critique of the ineffectiveness of some legislative items is provided by the European Environment Agency (2016).

The EAP (Environment Action Programme) proposed by the EC provides guidance for Europe's environmental policy until 2020, with the aim of transformation of the EU to become a sustainable green economy. The programme's key features are to protect the natural environment and to build a resource efficient low carbon economy. An analysis by the European Commission for the built environment shows that a 90% reduction in the emissions of buildings is possible by 2050. The directive is that all new buildings starting from 2021 shall be near zero energy buildings.

According to Lee (2009), the need is for an increased focus on the large number of SMEs (small and medium sized enterprises) that predominate in the business world. The result has been the generation of environmental policies concerning industrial activities. Because it has been demonstrated that legislative and regulatory pressures are more successful than anything else in persuading companies to adopt a sustainable supply chain (Naidoo and Gasparatos, 2018; Silvestre et al., 2018; Yin et al., 2018; Dubey et al., 2015; Singh and Gupta, 2014; Hanim et al., 2012; Wu et al., 2012; Hoejmose et al., 2012), all companies in every country in the EU must be fully aware of these directives.

2.6.1.1 Environment Action Programme (EAP)

The EU has been following environment action programmes since the early years of the 1970s. The European Commission's primary goal is to make sure that a common environmental action agenda is understood and followed by every EU state and every local and regional administration and is familiar to all stakeholders (European Commission, 2012a).

The environment action programme currently in force is EAP 7, which gives guidance on what must be done to meet EU environmental policy by 2020, EAP 6 having expired in mid 2012. EAP 6 identified four priority areas (Institute for European Environmental Policy, 2011):

- "climate change
- nature and biodiversity
- environment and health
- natural resources and waste"

EAP 6 covered the period from 2002 to 2012, during which time there was a dramatic shift in the economic situation globally which underlined the need to adopt a more flexible strategy. Assessment of EAP 6 shows that it made a significant contribution over almost every area of the environment (European Commission, 2011a).

A number of European Union countries suffered from the economic crisis and while trying to achieve fiscal reform as well as structural reform, but it could be that structural reforms will be seen as opportunities that can move them towards a strategy of sustainable energy and implementing EAP 7 may help do this.

The final draft of the proposed seventh EAP, to last until 2020, was presented by the European Commission on 29 November 2012, though part of EAP 6 was still in operation. The EAP 7 proposal named nine objectives as the EU's priority, and those relevant to construction industry are the protection, conservation, and enhancement of Europe's natural capital, the

European market to become a green and antagonistic low-carbon economy, and to strengthen the EU's legislative policies regarding the environment (European Commission, 2012a).

Responsibility for implementing those nine objectives effectively to achieving the union's main policy targets for the environment lies with the EU and its member states collaborating with public authorities, businesses and stakeholders.

2.6.1.2 Integrated Pollution Prevention and Control Directive (IPPC)

Policies addressing industrial emissions include the IPPC directive, which the EU adopted in 1996 for the approving and controlling of industrial installations. On the one hand, industrial sector businesses help the EU to grow in a sustainable way. On the other, most of the world's emissions of greenhouse gases come from industrial production, transport and agriculture (Halldorsson et al., 2009), demonstrating the necessity for a focus on sustainability to minimise environmental impact.

The IPPC directive is Directive 2008/1/EC and its aim is the integration of pollution prevention and control, stipulating what must be done in specific areas. Those relevant to construction industry are industries in the areas of chemicals, energy, metals, not excluding the minimisation and management of wastes (European Parliament and the Council of the European Union, 2008).

Every member state of the Union was obliged to report progress every 3 years on the directive's implementation in the following time periods: 2000 to 2002; 2003 to 2005; 2006 to 2008; and 2009 to 2011 to make it possible for the EC to evaluate the implementation of the industrial emissions directive.

2.6.1.3 Green Action Plan (GAP) for SMEs

According to Moore and Manring (2009), at least 80% of companies worldwide are SMEs and they form a significant component of the SC network, being able to act as suppliers, manufacturers, clients or participants of any form. They therefore have the potential to make an important contribution to improved supply chain management. SMEs constitute 99.8% of all European enterprises and are responsible for nearly 60% of total economic added value in Europe (European Commission, 2017). Every company, however small it may be, must provide to final consumers products and services that are clean and competitive.

Difficulties faced by SMEs in complying with environmental legislation include being unaware of EU policies and lacking the capabilities that will allow them to implement environmental friendly strategies (Brooks and Rich 2016; Done et al., 2011; Lee et al., 2009; Panwar et al., 2006) and it may be said that compliance becomes easier as the size of the company increases. In 2014, the European Commission in order to assist the compliance of SMEs with regulations and directives, adopted the Green Action Plan for SMEs (GAP), which "*intends to help SMEs take advantage of resource efficiency improvements, the circular economy and of green markets*" (European Commission, 2017). The aims, objectives, and opportunities for SMEs from GAP are summarised in table 2-2.

Table 2-2 : Objectives – Aims – Opportunities from GAP

Source: www.ec.europa.eu

Objectives	Aims	Opportunities
Raise SMEs' awareness of resource efficiency improvements and the potential of the circular economy for productivity, competitiveness and business opportunities	improve productivity	greening SMEs
Inform SMEs about EU resource efficiency actions under the COSME, Horizon 2020 and LIFE programmes, and the European Structural and Investment Funds.	drive down costs	green entrepreneurship
	support green entrepreneurship	opportunities for SMEs in a greener value chain
	develop European leadership in green processes and technologies	access to markets for green SMEs

2.6.1.4 Prevalent types of environmental legislation in the UK construction industry

As all other member-states of the EU, the UK government and local construction companies have to comply with EU directives. Some of the most prevalent ones, beyond the aforementioned ones above, are (CIOB, n.d.):

- 2010/13/EU – Energy Performance of Buildings Directive effective since 2006 and followed by more stringent amendments that came into effect in 2013. This directive impels buildings enhancements for better energy performance. Since 2006, this directive has brought the energy efficiency certificates for all properties.
- 1999/31/EC – EU Landfill Directive, which became a UK law in 2002 concerning the reclassification of waste ending in landfill (hazardous or non-hazardous) sites.

- 2008/50/EC – Ambient Air Quality Directive, dealing with air pollutants whose emissions can have a negative effect on public health and the atmosphere. (CIOB, n.d.)

In addition to these directives, the UK government issues laws to comply with EU legislation or other international conventions. Some indicative examples of UK legislation as demonstrated by the Chartered Institute of Building in the Carbon Action 2050 scheme are the:

Climate Change Act, in effect since 2008 to reduce carbon emissions by 80% until 2050. A five-year progress report will be submitted by the government during that period.

EPC and DEC, these are the Energy Performance Certificates and Display Energy Certificates for all buildings, either residential or commercial.

Carbon Reduction Commitment (CRC) Energy Efficiency Scheme. Under the CRC, the government rewards organisations for taking energy efficiency measures and punishes those who do not. This scheme has a corporate image impact as these companies are ranked according to their performance on that matter.

Other legislative schemes include Site Waste management Plans, Environmental Impact Assessments, Flood Risk Assessments and the Building Research Establishment Environmental Assessment Method (BREEAM) (CIOB, n.d.). The latter is

"[…] *the world's most widely used system for assessing, reviewing and improving a range of environmental impacts associated with buildings*". (CIOB, n.d., p. 9)

It needs to be mentioned here that the UK government provides various incentives to organisations. For example, it offers tax reliefs if a company installs renewable sources of energy; pays the total amount of energy saving machinery costs for the first year under the Enhanced Capital Allowances scheme. Moreover, there are other programmes which provide advice on energy efficiency issues to organisations and a various methods of financing initiatives towards waste management, recycling and supply chain efficiency improvements (CIOB, n.d.).

2.6.1.5 Environmental policies in Greece and current compliance with EU

As an EU member state, Greece is obliged to incorporate European environmental policies and supporting directives in national laws. Greece has a great many SMEs in service and industrial sectors and these SMEs generally have restricted financial resources and information systems less advanced than those available to larger companies. A company's ability to invest in equipment and technology is in inverse proportion to its size (Lee, 2009).

According to Baresel et al. (2007), implementation of EU Directives is problematic for many firms and is influenced by the absence of political will and the lack of a sufficient regulatory framework. Among the obstacles facing sustainability, according to Brooks and Rich (2016) and Panwar et al. (2006) are lack of knowledge and awareness concerning environmental regulation to come, and according to Lee (2009) and Lazuras et al. (2011) are a number of human factors and lack of expertise. Environmental perceptions in Greece are, unfortunately, limited and environmental legislation is implemented with less rigour than in Western countries which means that implementation of EU legislation and directives is delayed (Baresel et al., 2011).

The single most important aim for the EU is to reduce emissions of Greenhouse Gases (GHG) by 20% by 2020 in comparison with the base year of 1990 (European Commission, 2012b). Targets in subsequent years are generally higher: 40% by 2030 and 80% by 2050. Greece, on the other hand, has seen its total GHG emissions rise; in 2009 they stood at 122 million tonnes of CO_2 equivalent (Mt CO_2 eq.), 17.4% more than 1990 baseline emissions (IEA, 2011). More than 30% of the total carbon emissions in Greece are attributed to the building sector and more than a third of the total consumption of energy. The financial crisis that hit the country, has caused a drop in those figures. Almost two thirds of the houses in the country were built before 1980, therefore their energy consumption is very high compared to those in countries with similar climate conditions, i.e double the energy consumption of Portugal. One of the main reasons for that is the non-adherence to EU directives or other "international environmental commitments" of the country in the late nineties and the beginning of the new century (Bank of Greece Climate Change Impacts Study Committee, 2011).

It follows that adopting EAP 7 and observing the principal priorities, which are to protect, conserve and enhance EU natural capital making the EU a low carbon economy that is both green and resource-efficient, must be every member state's principal target. In common with all other member states, Greece is obliged to ensure that IPPC and IED directives and the ECAP action plan are enshrined in national legislation in accordance with EU deadlines.

Every member state in the EU must report every three years on the progress they have made in implementing IPPC directives. The time periods in question are: 2000 to 2002; 2003 to 2005; 2006 to 2008; and 2009 to 2011. According to EIONET (2013), the 4th Greek IPPC report for the period 2009 to 2011 in IRIS (the Industrial Emissions Reporting Information System) underlines the considerable difficulties faced by Greece in implementing the 2008/1/EC directive as a result of fewer employees being involved in the process, with most employees being in charge of additional operational duties.

Directive 2010/75/EU (IED) cancelled and replaced the IPPC directive in January 2014. IED was adopted in 2010 and the date by which it had to be incorporated into the national legislation of member states was 7 January 2013. Greece achieved this incorporation six months later, confirming the finding of Baresel et al. (2011) that the low level of environmental perceptions in Greece delayed EU directives and legislation implementation.

2.6.1.6 The Greek Sustainability Code

In UK, the government has created an online platform for companies not obligated to disclose non-financial data to voluntarily report their carbon footprint. That programme was initiated in 2013/14. In Greece, the sustainability code (Sustainable Greece 2020, 2017) complies with legislative regulations and is actually a copy of the German sustainability code; it is presented on the social online platform, whose members are business associations, private and public organisations, local authorities, non-governmental organisations (NGOs), and concerned citizens. The sustainability code is a set of twenty criteria that organisations need to fulfil. The Sustainability Observatory, a branch of Sustainable Greece 2020 publishes a report annually, although the last available publication found is dated in 2014-15. From that year’s report, figure 2.6 shows best practices classification of the participating groups (top pie-chart), while the bottom three charts illustrate the orientation of the three groups.

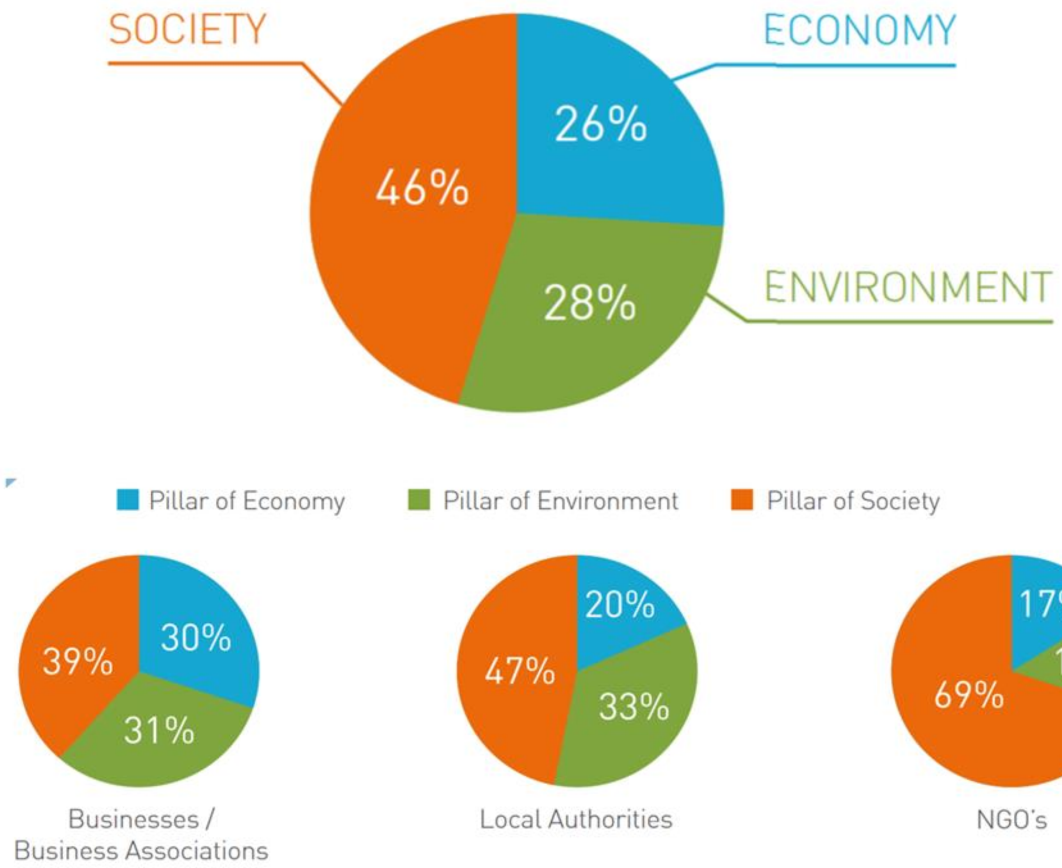


Figure 2.6: Focus of Greek participants in sustainable development actions

Source: www.sustainablegreece2020.com

It can be seen from figure 2.6 that greater focus is being given to social sustainability by all parties involved. This is most likely attributed to the severe impact of the financial crisis hitting the country on the society.

2.6.2 Environmental policies and Sustainable Supply Chain Management (SSCM)

The rise of the global population is expected to have a significant impact on energy, food and a variety of natural resources. Estimates forecast that the world outlook in 2050 will feature greater disruption, faster loss of biodiversity, increased demand for water, and a serious impact on health unless more green policies are in place to deal with projected demand for energy and food (European Commission, 2012b).

Sustainability is therefore a challenge facing companies, given that pressure will come not only from government, customers and regulatory bodies as well as other stakeholders for services and products that are more sustainable, but also from climate change. Adopting green policies is a *sine qua non* if development is to be sustained and competitive advantage over those unable to follow is to be obtained. Although sustainability's environmental dimension has been the subject of a great deal of study (Silvestre et al, 2018; Yin et al, 2018; Singh and Gupta, 2014; Bag, 2013; Saha and Darnton, 2005), the social dimension has received little attention (Al Khidir and Zailani, 2009; Lee and Kim, 2009) and this also applies to integration of the 3 dimensions (Ekins, 2005). Examination of sustainability must cover the whole of the upstream and downstream supply chain and cross a single firm's borders (Saeed and Kersten, 2019; Pimenta and Ball, 2015) to assist companies in improving both collaboration and the efficiency of their supply chain (Beamon, 2008).

Population and energy challenges ahead make more necessary a proactive involvement in initiatives for sustainability (Hanim et al, 2012; Ramanathan et al, 2010; Baumgartner and Ebner, 2010; Porter and Kramer, 2006; Graafland and Ven, 2006;), and for proactive environmental policy adoption. This has the potential to reduce risks linked with environmental adherence, and create innovative-sustainable products and SC that competitors will find difficult to copy (Porter and Kramer, 2006; Zutshi and Sohal, 2004).

A promising private initiative concerning the construction industry is the Concrete Sustainability Council, dedicating itself to awarding certificates for "*the production of green or sustainable concrete by assessing the entire concrete supply chain.*" (Concrete Sustainability Council, 2017). The council developed by cement organisations from four continents, excluding Australia and Africa. The European Construction Sector Observatory welcomes this initiative as evidenced in Trends Paper Series (European Commission, 2019).

The European Commission provides the following statement, describing the construction value chain:

"*The construction value chain includes a wide range of economic activities, going from the extraction of raw materials, the manufacturing and distribution of construction products up to the design, construction, management and control of construction works, their maintenance, renovation and demolition, as well as the recycling of construction and demolition waste."* (European Commission, 2016, p.3).

2.7 Environmental Management Systems

2.7.1 Environmental Management Systems and Supply Chains

Organisations are part of many supply chain networks where an Environmental Management System (EMS), closely linked to and combined with Green Supply Chain Management practices (GSCM) (Sarkis, 2012), provides integrated tools for the identification and consolidation of sustainability between these networks. Both environmental management systems and Green Supply Chain Management practices have significant effects on the environmental sustainability of an organisation. Nonetheless, since all companies being part of the network do not inherently share organisational goals regarding the environment,, its environmental sustainability is unattainable without the incorporation of GSCM practices (Preuss, 2005). Hence, the adoption of EMS without a distinct presence (or even with a total absence) of GSCM might have a much limited environmental benefit; on the other hand, according to Darnall et al. (2008) the adoption of EMS, along with GSCM, reinforces the effectiveness of the environmental impact across the entire network of an organisation and beyond its boundaries.

According to Darnall and Edwards, (2006) EMS are management schemes that determine the ways an organisation tracks, controls and responds to its impact on the natural environment, allowing them to steadily reduce those impacts. Therefore, as Shireman (2003) opines, the primary objective of an Environmental Management System is to promote a more comprehensive approach towards the integration of environmental practices into the company’s operations, thus preserving and protecting the environment becomes one of the principal constituents in the development of its corporate strategy.

The initial stage of the plan - do- check - act model, where an Environmental Management System is ground on, is the development of environmental actions and guidelines. Then, followed by the execution of tasks necessary for the fulfillment of the defined objectives, systematic checks to establish that those objectives are met and finally by undertaking all necessary action via adjustments to guidelines, objectives and goals (Matthews, 2003). According to Anand et al. (2009) EMS is a consistent and organised method that aims at the implementation of new measures and at the search for new ways for process efficiency improvement.

2.7.2 International Standards of Environmental Management Systems

The United Nations Conference on Environment and Development was held in 1992 in Rio de Janeiro and underlined the major role enterprises play in environmental protection, thus, according to Steger (2000), leading to the development of the two best- known and accepted environmental management ESMs: ISO 14001 and the Eco-Management and Audit Scheme (EMAS). The former is developed by a private entity – the International Organisation for Standardisation– and EMAS is governed by the EC Regulation 1221 / 2009. The adoption and application of the ISO 14001 standard, in addition to the benefits it accrues for an organisation, it can also assure and equip with confidence all involved parties within the company and its external stakeholders that the environmental impact is measured and can potentially be enhanced. ISO 14001 though is not a provider of environmental performance requirements; it only provides the environmental framework for organizational adaptation (ISO, 2014).

EMAS, is an optional environmental management instrument which encourages the continuous evaluation and improvement of the company's environmental performance, enhancing its credibility and transparency. Although considered a significant proactive-tool for the ongoing management of environmental impacts, approximately 8.150 sites are enrolled in EMAS and it is currently used only by 4.500 organisations (EMAS, 2014). On the contrary, ISO 14001 users increase every year. Almost a decade ago, Yin and Ma (2009) claimed that more than one hundred thousand certificates have been issued. According to Stalley (2009), these certificates were issued in more than a hundred countries around the globe. According to ISO, by the end of December 2012 the number of certificates issued reached 285.844, while the registered states reached 170. Without a doubt, ISO 14001 has captured the interest of industries, governments and companies around the world that aim at remaining competitive and aspire to the advancement of their environmental systems (Sambasivan and Fei, 2008).

Differences between these two certifications can be identified in a number of fields. Firstly, ISO 14001 is sold by private accreditation providers whereas EMAS is issued by a public body (Neugebauer, 2012). Their geographical availability also varies; ISO 14001 is valid and available globally since its presentation in 1996, while, according to Testa et al. (2013) EMAS had been limited in Europe and has extended its outreach since 2010. In addition, the two EMS models follow different rapprochements: the development and provision of specific guidelines that will contribute to the companies' effective environmental management and will be applicable by all types of companies globally, remain the main focus of ISO 14001 (Morrow and Rondinelli, 2002); EMAS is more set on changing environmental performance.

Companies should use these two management tools in a complementary manner and not as substitutes, in order to achieve long-term and meaningful impact on environmental performance (Testa et al. 2013). According to Schmidt and Osebold (2017) in the available national registry of 2013, less than 2% of German construction companies obtained an EMAS, while the manufacturing industry was leading with 18%.

Darnall (2006) claims that ISO 14001 has gained wide recognition amongst environmental standards and affects the environmental sustainability of companies on a global level, and according to Routroy (2009) provides guidelines regarding the impact of their operations on the environment and promoting practical environmental-related guidance. The application of ISO 14001 clearly depends upon the companies’ adherence to the policies regarding pollution prevention. This can be interpreted further as the companies’ commitment to regular measurements of the impact of their activities on the environment through the implementation of the PDCA model, opine Zhu et al. (2013), as well as a commitment for stable and unceasing enhancement as a significant element of this model, according to Brouwer and Van Koppen, (2008).

2.7.3 Stages of Environmental Management Systems adoption

Adopting an effective Environmental Management System is an intricate process that aims at keeping environmental-related issues in a wieldy level. According to Jabbour et al. (2013) in order for this process to run smoothly it should involve three stages, reactive, preventive and proactive. According to the authors, when the system is implemented during the reactive-stage, it involves the company’s desire to comply with existing environmental legislation, whereas, as Jabbour and Santos (2006) state, the adoption of EMS in the preventive stage occurs when companies aim at boosting their environmentally-related performance and preventing or reducing emissions. Lastly, Boiral (2006) claims the application of EMS in a proactive stage is encompassed towards obtaining and ensuring organisational antagonism.

In addition to the aforementioned stages, other authors distinguish another approach that companies need to follow in order to establish and maintain a strong EMS, which is comprised of five steps that relate mutually to the implementation steps of ISO 14001 and its PDCA cycle. The steps are: (a) development of environmental actions and objectives (b) identification of the areas to which EMS are addressed (c) implementing and operating along with rational allocation of resources d) check and monitor of the development in regards to the set guidelines and identification of the corrective actions to be followed in case of error or deviations. (e) management review with emphasis on continuous improvement through the development of new environmental objectives (Arimura et al., 2011; Kirkland and Thompson, 1999).

The successful adoption and sustainability of EMS both during this cycle and at every stage independently, lies on various factors that are crucial and determine the level of success. Zutshi and Sohal (2004a and 2004b) conducted a survey on the adoption of EMS by Australian companies; in this survey, the authors place emphasis on the vital role senior management and employees play in all steps of the EMS procedure. Their engagement is highly valued during all five cycles, from start all the way to final improvements. Appropriate training to employees, maintenance and upgrading of existing structures and equipment are also instrumental in the process of adopting EMS (Sambasivan and Fei, 2008). According to the same authors, the implementation process is regulated and affected not only by the aforementioned internal factors but also by external ones such as customers, government policies and stakeholders, who expedite the procedure by applying varying degrees of pressure.

Pun et al. (2002), considering all of the stages required and the parameters that affect EMS, have designed a model for the effective planning of EMS, which comprises of five stages: (1) devise environmentally-related strategy (2) assess motivation, occasions and obstacles related to EMS, (3) develop functional organisational structure, (4) create and implement systems and (5) assess EMS' competitive impact.

2.7.4 A critical view of Environmental Management Systems

An organisation that has implemented EMS and wishes to gain certification according to the ISO 14001 standard should consult an accredited, independent auditor that will provide guidance throughout the process. An ISO 14001 certification acknowledges the compliance of the company's EMS with internationally recognized standards; it also demonstrates, as well as confirms, the company's commitment to unceasing improvement and the efficiency of the management system that the company has put to use (Darnall, 2006). Organisations that had adopted an EMS before ISO 14001, received additional recognition and benefited socio-economically once they acquired the ISO 14001 (Darnall et al., 2008). Therefore, as King et al. (2005) and Potoski and Prakash (2005) commend, EMS do not only upgrade organisations' environmental performance but are also connected with enhanced productivity, efficacy during the production process and customer satisfaction, paving, thus, the way towards new opportunities, supporting the similar views of Darnall et al. (2001) and Sambasivan and Fei, (2008).

The adoption of EMS has a positive effect on a company's economic performance (Nishitani, 2011) and their implementation boosts and promotes its image, thus enhancing its competitive advantage (Giménez Leal et al., 2003) and creating positive relations with authorities (Morrow and Rondinelli, 2002). Therefore, the role of EMS in the advancement of a company's environmental and business performance is increasingly being recognized (Curkovic et al., 2000). Furthermore, EMS function as a protector against competition and the critics over the company's environmental impact (King and Lenox, 2001).

However, the implementation of EMS such as ISO 14001 has been quite a controversial issue amongst researchers. A number of them support the notion that this measure can actually bolster the company's environmental performance (Psomas et al., 2011; Matuszak-Flejszman, 2009) while others, like Montabon et al. (2000), question its effectiveness (Montabon et al., 2000, Hui et al., 2001, Boiral and Henri, 2012).

Moreover, researchers like Honey and Stewart also raise doubts regarding the effectiveness of EMS (2002) and the level of improvement achieved during their application, mainly due to the regulatory pressures involved, as well as to the fines and penalties issued to a company when it does not comply to those regulations (Davidson and Worrell, 2001). These doubts are further enhanced by the fact that the successful implementation of the proposed environmental actions cannot be verified by external stakeholders (Rondinelli and Vastag, 2000).

In addition, according to Steger (2000) the rationalization of a company's economic and environmental objectives via EMS – implemented on a voluntary basis– cannot, under any circumstances, substitute the official regulations protecting the environment. Bansal and Hunter (2003) claim that Environmental Management Systems are thought as a company's effort to enhance its image, thus failing to lead to desirable reductions of the negative effects to the environment.

In addition, scholars, like Tinsley, question the reasons behind the adoption of EMS, stating that companies consider them to be less of an environmental policy and more of a competitive advantage, an opportunity for business development and market leadership (2002). Others claim that the benefits that ensue from the adoption of EMS are limited in the company's operational procedures and possibly do not extend to the entire supply chain network (Handfield et al., 2005).

In view of the above and taking into account the increasing number of EMS adopted (ISO 14001 certifications in particular) and the respective benefits of their implementation, as well as the skepticism in regards to their effectiveness, one can easily conclude that, nowadays, environmental sustainability ranks high on both governments' and corporations' priority list globally. Regardless of the reasons behind the adoption of EMS– whether it involves compliance to the regulations, update of the company image or boost of the company's competitive advantage– meeting environmental objectives and policies has become a key element in the companies' management agendas. ISO 14001 has evolved into a valuable environmental management tool that can function on a microeconomic level as well as on a macroeconomic one (Seiffert, 2008).

2.8 Life Cycle Assessment (LCA)

2.8.1 Insights of LCA

Many companies –nowadays even more so– face challenges associated with environmental issues. Legal directives and guidelines constitute a mechanism that imposes pressure not only on the production process but also to the product itself. In view of the above, the integration and management of environmental data has become imperative and environmental impact control has been taken a step further to include the entire product life cycle. While EMS can be viewed as vertical integration of environmental information, it is necessary to take into account the product lifecycle and incorporate the horizontal dimension (Eun et al., 2009).

From idea to design and then to use, end-use, reuse or disposal, every product or service, follows a certain life-cycle which comprises of various stages that respectively incorporate a number of activities. During these stages of the production process, resources are consumed and substances are emitted, thus affecting the environment. The environmental impact of these processes, as Rebitzer et al. (2004) claim, takes on diverse forms and ranges, greatly affecting the human health as well as the whole eco-system.

The LCA is a systematic and precise technique that offers a holistic assessment of the environmental impact materials and products have throughout their lifecycle, from raw material extraction and processing, to manufacture and use, distribution and disposal or recycling (Ny et al., 2006). According to Reap et al. (2008), it is considered to be a major and top-level tool that finds widespread application throughout the cradle-to-grave cycle of products. The Johannesburg Declaration on Sustainable Development, adopted by the UN

General Assembly in the 2002 Earth Summit, highlighted the importance of LCA in achieving production that is sustainable, as well as consumption, according to Hertwich (2005).

The use of the Life Cycle Analysis has increased all these recent years. Scientific literature includes more than 4,500 scientific articles on LCA published until 2010 (Notarnicola et al., 2012). Guinee et al. (2011) in their analysis of LCA evolvement over time, offer a detailed view of the various stages LCA has progressed throughout the years and group them into phases. First, during the decades of the seventies and eighties there was the birth of the LCA idea. Then, in the decade of the nineties was that of standardisation, followed by the first decade of the new century described as the "elaboration- decade", and reaching the current decade which is characterized as the "Life-Cycle Sustainability Analysis" decade.

LCA has been in the scope of the International Organisation for Standardisation (ISO) which, in the course of these decades, has published a set of standards that have been constantly reviewed and supplemented. At present, two are the globally dominating standards concerning the analysis of a product's or service's life-cycle, both from the 14000 family of the International Organisation for Standardisation. First, the ISO 14040, which according to ISO (2006a) focuses on "principles and frameworks", and second the ISO 14044, which provides the "requirements and guidelines". The life-cycle assessment framework that those systems are based on are demonstrated in figure 2.7.

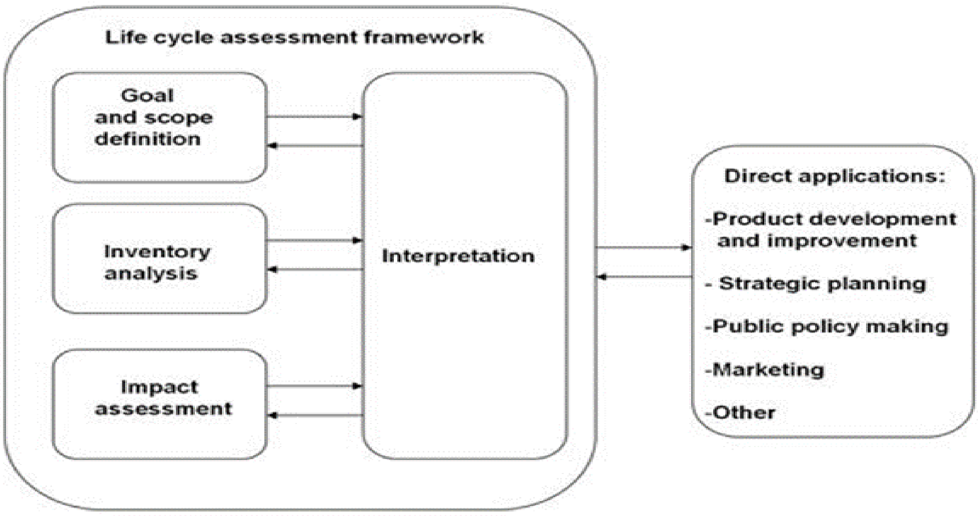


Figure 2.7: Life Cycle Assessment framework

Source: International Organisation for Standardisation (2014)

Figure 2.7 delineates the four stages of assessment's framework and its relationship with various direct applications. According to Finnveden et al. (2009), the first stage is of high importance as it designates not only the product that is subject to study but also its boundaries, as well as the functionalities of the product/service, examined as units.

The Life Cycle Inventory involves the assortment of all raw materials (inventory) of all necessary input-values (i.e. resources) and output-values (i.e. associated emissions) in reference to the product that is under study (DeBenedetto and Klemes, 2009). LCIA examines and determines the environmental impacts (e.g. climate change or resource depletion, to mention but a few) of the above mentioned inputs and outputs (Pennington et al., 2004). The data collected from stages a-c are analyzed and interpreted accordingly, providing useful information, recommendations and alternatives in regards to the management of the environmental impacts, reaching and summarizing conclusions on LCA study (Rebitzer et al., 2004).

In spite of the above, many scholars and researchers have identified LCA deficiencies. For instance, the ISO 14040 standard proposes a broad framework/model for Life Cycle Assessment but is not detailing LCA-related tools nor suggests particular, clear-cut methodologies to be applied in the above-mentioned phases (DeBenedetto and Klemes, 2009). In this respect, Rebitzer et al. (2004) place emphasis on the fact that although the product design phase affects the environmental impacts of later stages of the product's life cycle, it is not taken into account in LCA, thus imposing limitations on the conclusions drawn. Finkbeiner et al. (2006) underline that LCA focus is limited on environmental aspects and impacts, excluding the socio-economic dimensions. Being able to fulfil all pillars of the Triple Bottom Line and not only the environmental one, the Life Cycle Assessment methodology will have to expand in the future and evolve into Life Cycle Sustainability Assessment (LCSA) to incorporate the other two pillars (Guinee et al., 2011).

In this thesis, we shift our focus from the general LCA strengths and weaknesses to the main types of Life Cycle Analysis, namely the process, input – output, and hybrid, which will be presented and analysed in detail in the section that follows.

2.8.2 Analysis of the Life Cycle Assessment types

The holistic approach is the main asset of LCA; it constitutes, however, one of its weaknesses, a kind of Gordian knot that needs to be unraveled by clearly defining system and time boundaries so that results will not be significantly affected. Boundaries are, therefore, pivotal to LCA (DeBenedetto and Klemes, 2009).

2.8.2.1 The Process Life Cycle Assessment

Process LCA is a "bottom-up" process analysis applied in studies regarding the cradle – to - grave environmental impacts of independent items/products, which means that it is usually limited in a particular company (Wiedmann and Minx, 2007). The fact that site and time specific data are used, instead of average ones, allows a detailed analysis of all the information accumulated and constitutes process LCA's main strength (Lewandowska and Foltynowicz, 2004). In opposition, Lenzen (2000) claims that the use of such site and time specific data is so detailed that general conclusions cannot be reached, leaving open the possibility of a "truncation error" of almost 50% by estimating only first and second-order impacts. Therefore, and according to Lewandowska and Foltynowicz (2004), process LCA offers analysis only on microeconomic and not macroeconomic level, as data is often limited by site and time and parts of the process are excluded or oversimplified. On the same page, process LCA should not be used to perform a comprehensive supply chain analysis since, in that case, boundaries are vast and not easily discernible (Weiser et al., 2013). With regard to the analysis of carbon dioxide emissions, Wiedmann and Minx (2007) support the aforementioned views, stating that if applying the LCA process to a bigger entity, it could lead to shattered results/outputs.

2.8.2.2 The Input-Output Life Cycle Assessment

The Input-output LCA is a "top-bottom" process used in lieu of process LCA (which is, as previously mentioned, a "bottom-up" approach). Its roots can be tracked back to the 1920s, in Economic Sciences Nobel Prize winner Leontief's original ideas and work which involve the study of industry interdependence nationwide (Suh, 2003). Input-output tables indicating, on average, production-related monetary transactions between industry sectors are frequently published in most industrialized countries and contribute significantly to LCA by providing information on resources' use and environmental emissions (Finnveden et al., 2009). Furthermore, according to Weiser et al. (2013), the fact that interactions between all economic sectors are recorded in these tables, defines the whole economy as the limit, and thus, according to Heijungs and Huijbregts (2004), enabling the estimate of upstream environmental impact , and providing an economy-wide approach without the need for system cut-offs (Wiedmann, 2009). Despite however the lower cost and the fastest performance of the I/O LCA approach, certain drawbacks can be detected, focusing mainly on two elements. Firstly, the analysis of heterogeneous sectors might not look upon a specific process in a comprehensive and precise manner; secondly, the fact that I/O LCA is only production-phase related is a source of concern for researchers, as the results from use and disposal are not taken into account (Hendrickson et al., 1998). Finally, data availability only on industry level (Hertwich, 2005), according to Heijungs et al. (2006) makes measurement of impacts on single products impossible.

2.8.2.3 The Hybrid Life Cycle Assessment

Hybrid LCA (Suh, 2003) was introduced to combine, balance and capitalize on the advantages of process LCA and I/O LCA methods, leaving out drawbacks like limited process precision or cut-offs. Three distinct types of hybrid Life Cycle Assessment analyses exist, namely the tiered-hybrid, the I/O based and the integrated one (Suh and Huppes, 2005).

In an attempt to analyse deeply the unit process and the upstream flows linked to this process (Moriguchi et al., 1993), the researchers combined process LCA and I/O LCA, thus creating the tiered-hybrid analysis process. In 1999, Joshi followed the reverse path, dividing existing sectors from the input-output table into subsectors or introducing new theoretical ones, thus presenting a combined method, named the I/O hybrid analysis. A new hybrid method, known as the integrated hybrid approach, which incorporates the LCI matrix approaches along with I/O analysis in a comprehensive, high-fidelity computational model was presented in 2004 (Suh, 2004).

Hybrid analysis makes use of both process LCA strong point of detailed analysis and of the broader approach provided by the I/O LCA method (Haes et al., 2004), generating a more balanced and clearer picture (Finnveden et al., 2009). It is for those reasons that Eun et al. (2009) acknowledge hybrid LCA as the most conclusive and applicable of all LCA types.

The strong and weak points LCA, I/O LCA and hybrid LCA are displayed in figure 2.8, below:

	Process LCA	I/O LCA	Embedded hybrid
Analysis of specific product types	+	−	+
Completeness of inventory items	−	+	+
Included exchanges types	+	−	+
Uncertainty of exchanges	−	+	+

Figure 2.8: Comparison of the three LCA approaches

Source: Thrane *et al*. (2007)

2.9 Supply Chain Environmental Analysis Tool (SCEnAT)

The previous discussion on supply chains has made clear that the typical supply chain is complex, non-linear and multi-entity. Koh *et al*. (2013) suggest that the majority of tools currently available are specific to individual sectors and have as their central focus the calculation of carbon emissions; they do not cover carbon emission management, even though that is more important than calculation. While tools are available separately for calculating and managing carbon emissions, their very separateness creates boundary issues that prevent them being a good fit with the tenor of the SC and allow truncating mistakes to be present in the data. It is also true that the majority are only diagnostic tools and do not offer solutions. The same authors therefore highlighted the fact that, if supply chain performance is to be both evaluated and improved, a tool that integrates the calculation and the management of carbon emissions is required.

SCEnAT is designated to do just that, and covers the whole economy with intervention at four different levels, namely the product, the process, the company, and the supply chain level. Underscoring the functions of the tool is the belief that, if a low carbon supply chain is to be achieved or a product's supply chain freed from carbon, it is a necessity to gain full awareness of the product's life-cycle taking into account every source and every level at which carbon is emitted (CLCF, 2011). Linton *et al* (2007) point to the necessity, if a supply chain is to become green, to integrate awareness of environmental matters into every stage of the supply chain. These include design of the product, raw material procurement, production and distribution, consumption, and disposal.

While other tools are available, SCEnAT is regarded to stand at a higher level than the rest, based on the comparison of its features with those of three other tools, pinpointing at the superior advantages of SCEnAT (Koh et al., 2013). The first of these is EMIT (Emissions Inventory Tool). The second is modelling software by AB Agri. The third is CCalC, which has recently been updated into version 3.3 and it can be downloaded free of charge from http://www.ccalc.org.uk/, making it even more attractive. Their comparison is presented in Table 2-3, which illustrates the advantages offered by SCEnAT.

As table 2-3 makes clear, SCEnAT's advantages lie in the integration of its supply chain modules. This idea is developed in figure 2.9, which illustrates the logical steps followed by SCEnAT modules, starting with the SC mapping.

Table 2-3: Advantages of SCEnAT over other available tools

Source: CLCF (2011)

FEATURES TOOL/SOFTWARE TYPE	TYPE 1	TYPE 2	TYPE 3	SCEnAT
CARBON CALCULATION	Yes	Yes	Yes	Yes
SC MAPPING	N/A	N/A	Not clear	Yes
CARBON HOTSPOT IDENTIFICATION	N/A	N/A	Not clear	Yes
METHODOLOGY	Emissions inventory & formula based calculations	Very Basic LCA	Comprehensive LCA	Process LCA + I/O analysis nased LCA
INDUSTRIAL ACTIVITY COVERAGE	Sectoral focus	More than one sector	More than one sector	Entire economy
BEHAVIOURAL FLEXIBILITY WITHIN THE APPROACH	Little oor no Flexibility	Some flexibility	Good flexibility	Complete flexibility
AVAILABILITY OF OPTION FOR INTERVENTIONS	No	No	Yes	Yes
LEVEL OF INTERVENTIONS	N/A	N/A	Three	Four
IMPACT ESTIMATION	No	No	Yes	Yes
TYPES OF IMPACTS	N/A	N/A	Environmental and economic	Social, economic, environmental
OPTIMISATION OF CARBON FOOTPRINTS	N/A	N/A	Yes	Yes
IN-BULT DATABASE	Yes	Not clear	Yes	Yes
CASE STUDIES	No	No	Yes	Yes
COMPREHENSIVE SYSTEM KNOWLEDGE BASE	No	No	No	Yes

2.9.1 Supply Chain Mapping

SCEnAT's first stage views the life-cycle of the product holistically, mapping the entire flow of operations from beginning to end of the supply chain that have any bearing on the life-cycle of the end product. The inputs needed for the production of a complete are as follows (Koh *et al*., 2013):

- each component's original source
- all companies forming part of the upstream supply chain
- energy use at each level in the chain
- the manufacturing company's production processes
- details of all storage, transport and distribution operations throughout the supply chain and of all reverse flows including waste during production and disposal and recycling of finished goods after use.

What makes the mapping module so important is that, in ensuring the consideration of every indirect as well as direct input throughout the supply chain, it sets the boundaries and scope to assess carbon emissions and identifies carbon hotspots in the supply chain that the company should target (CLCF, 2011).

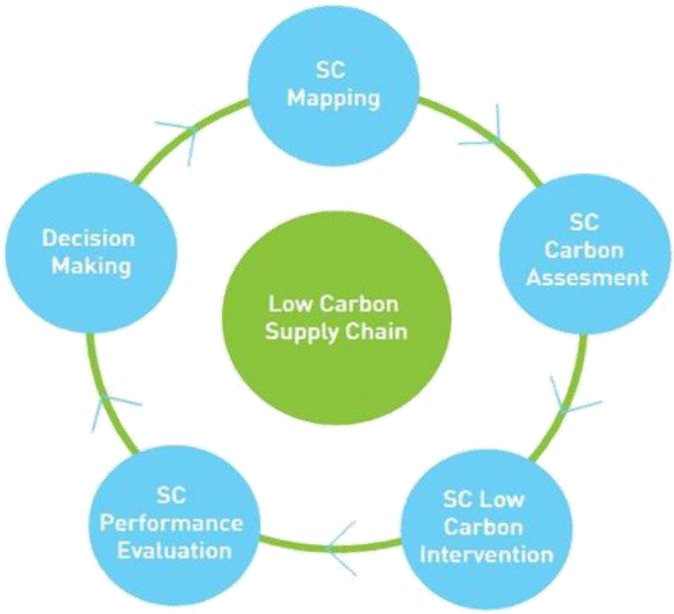


Figure 2.9: Design of SCEnAT

Source: CLCF (2011)

2.9.2 Supply Chain Carbon Assessment

SCEnAT uses a hybrid LCA approach, combining process LCA and environmental input-output LCA to analyse data from the mapping module to identify carbon hotspots. According to Rowley et al. (2009), the process LCA, because it focusses on product-related data, is not considered as a complete methodology, which, by configuring the limits at company level, is only partly efficient in the assessment of a whole supply chain's carbon emissions. This is illustrated in figure 2.10.

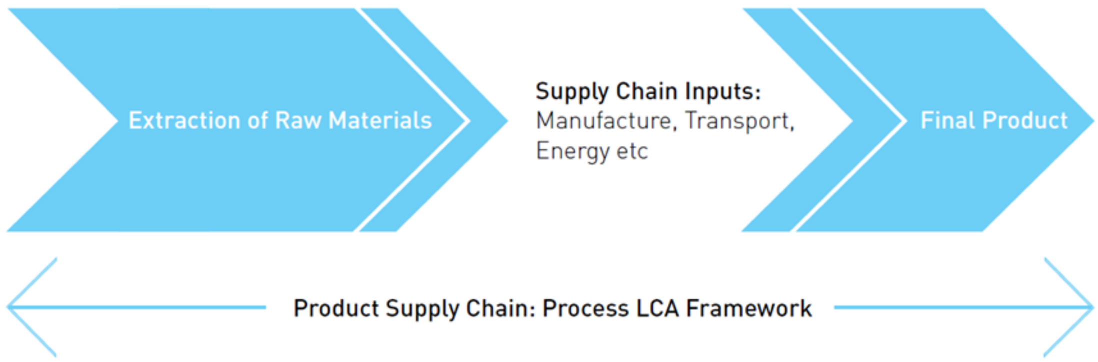


Figure 2.10: Process LCA framework

Source: CLCF (2011)

Figure 2.11 demonstrates how input-output LCA completes the data by taking the boundaries beyond the company level (Suh and Huppes, 2002), thus, the effects and indirect inputs of all economy's sectors, are now taken into account.

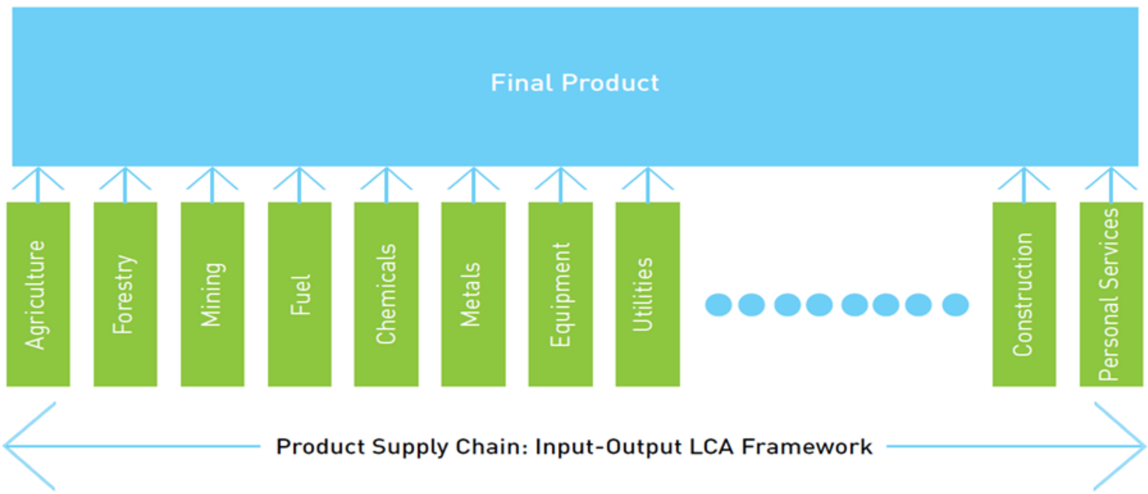


Figure 2.11: Environmental Input-Output LCA

Source: CLCF (2011)

According to Acquaye et al. (2011), by combining data specific to the process with inputs from extended boundaries, hybrid LCA exploits the advantages of both methodologies. Table 2-4 shows how SCEnAT uses hybrid LCA.

Table 2-4: The benefits of hybrid LCA

Source: CLCF (2011)

PROCESS LCA		ENVIRONMENTAL INPUT-OUTPUT LCA	
DISADVANTAGES	ADVANTAGES	ADVANTAGES	DISADVANTAGES
	More accurate		Less accurate
	Product and process specific		Generic and results are aggregated
Truncated system		Comprehensive system boundary	
Time consuming to develop inventories		Can assess impacts attributed to imports	
	Estimate Scope 1 and 2 emissions	Estimate Scope 3 (indirect) emissions	
	BENEFITS OF HYBRID LCA METHOD		

SCEnAT therefore, facilitates assessment of not only direct Scope-1 emissions, but also of indirect Scope-2 and Scope-3 emissions. Emissions generated in all three scopes are illustrated in figure 2.12. Huang *et al*. (2009) have shown the vital importance of taking account not only of the company's direct emissions and those attributable to it because of energy purchases, but also of the Scope 3 emissions that are responsible for more than 75% of industry's carbon footprint.

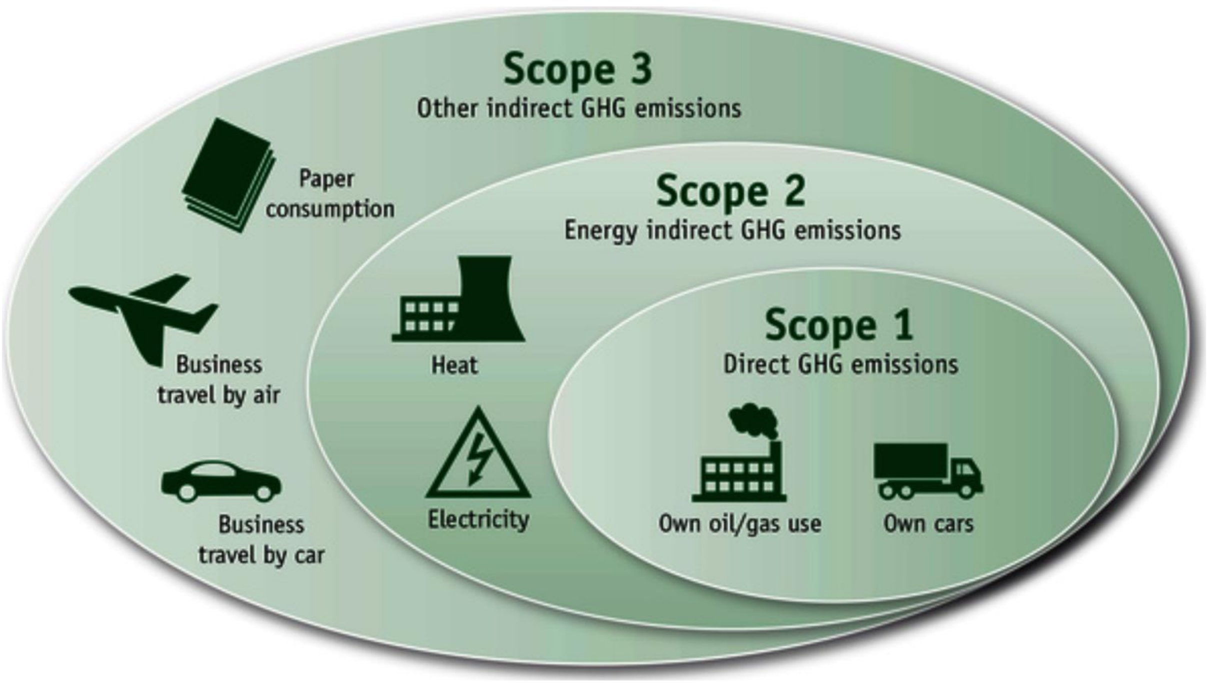


Figure 2.12: Direct and indirect emissions

Source: Forest Carbon Group (2017)

2.9.3 Interventions on Supply Chains

SCEnAT's third module suggests interventions that target the carbon hotspots identified in modules one and two to reduce emissions and develop a low carbon SC. According to Koh et al. (2013), in SCEnAT, any decisions leading to a reduction in CO_2-equivelant emissions in a SC, are defined as low-carbon interventions. SCEnAT Module-3 draws on a database that stores information about low carbon intervention and comprises at present the sixteen broad intervention typologies presented in Figure 18. These sixteen typologies are sub-divided into categories. SCEnAT offers a number of interventions for each broad type, providing brief descriptions and, where possible, an estimate of the reduction in CO2 emissions that may be expected from an intervention (CLCF, 2011).

Table 2-5: Possible areas of SCEnAT's interventions.

Source: CLCF (2011)

BRAND INTERVENTION TYPE	DESCRIPTION
1. TECHNOLOGICAL	Investment in more efficient technological equipment and machinery.
2. ICT	Green IT software and hardware solutions.
3. BUILDING	Methods of greening buildings (new builds and retrofitting).
4. LOGISTICS AND TRANSPORT	Options for reducing emissions relating to logistics (the transportation of goods, personnel, and delivery of services).
5. ENERGY INTERVENTIONS	Interventions relating to scope 1 and 2 emissions from energy production and consumption on site.
6. PROCESS AND PRACTICE	Alteration in process/practice within firm or supply chain to reduce energy used in comparison to old process.
7. PRODUCT, PACKAGING, AND WASTE	Reductions in emissions by product alteration and or the prevention/reduction of waste going to landfill throughout the supply chain.
8. PROCUREMENT	Reduction of supply chain emissions through environmental requirements and carbon reductions detailed within procurement contracts.
9. OFFSETTING AND CARBON NEUTRALITY	Quantifiable offsetting of overall CO2 emissions through offsetting (offsetting does not represent an actual reduction in CO2 emissions and therefore should not be reported as such).
10. AWARENESS	Interventions used to raise awareness of staff/supply chain partners enabling behavioural change with associated reductions in emissions.
11. EMPLOYEE	Formally employing personnel with environmental responsibility. Altering corporate governance structure to assign environmental responsibilities to existing staff.
12. STRATEGIC	Development of strategy and policy to enable an understanding of resource consumptive practice and activities in order to tackle carbon emissions.
13. SUPPLY CHAIN/NETWORKED	Intervention undertaken as part of a wider network or organisations.
14. KNOWLEDGE BASED	Interventions stimulated via consultancy, knowledge exchange, or other case based learning.
15. BOLT ON	Intervention that is not central to firms' carbon footprint.
16. END USER	Behavioural change at point of use. Use/disposal of product and/or service in a more environmentally aware manner.

2.9.4 Supply Chain Performance Evaluation

The last part is related to modules 1 and 3. In assessing a supply chain's environmental performance, SCEnAT takes account of the need for decarbonisation not to produce negative effects and not to increase costs of transport and distribution through the interventions it recommends, and so this module assesses possible results of an intervention. This gives companies a clear picture of the possible effects on performance of adopting a particular strategy to take the carbon out of the supply chain. KPI (key performance indicators) developed through literature review and consultation are used to assess interventions' efficiency and effectiveness (Koh et al., 2013). Key performance indicators are divided into three distinct classes, thus economic, social and environmental, so that the performance of the supply chain can be evaluated on a multi-dimensional basis and with a 3BL focus to ensure sustainability. Figure 2.13 summarises the benefits to an organisation and its supply chain of using SCEnAT.

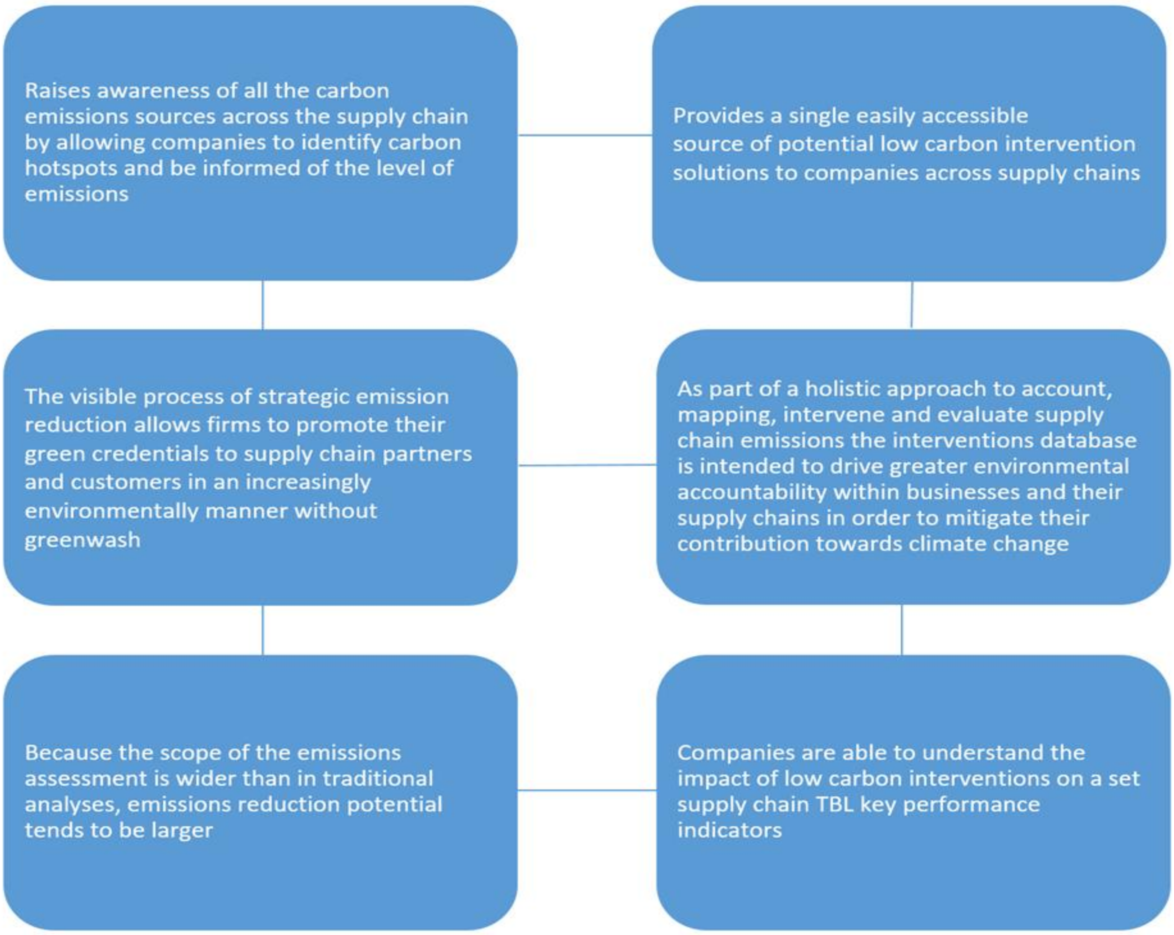


Figure 2.13: Benefits of using SCEnAT

3 Research Methodology

3.1 Introduction

There are three different approaches incorporated in this thesis to provide answers to the research questions. First, a systematic literature review is conducted to answer the extent of scientific coverage, evidenced by academic journals, of environmental sustainability in the UK construction industry. The details of this approach are presented in section 3.2 below. The second approach is a qualitative study using interviews as its research instrument in tackling the second and third research questions while using mixed methods of purposive sampling implemented in two countries, UK and Greece. The details of this approach are presented in section 3.3. The third approach is a case study of a small-to-medium-sized (SME) construction company in Greece, where the researcher applies a state-of-the-art decision support system (SCEnAT) to provide the answer to the fourth research question. Section 3.4 discusses the data requirements from the case study. The research questions, as presented in the introductory chapter, are as follows:

- **RQ1:** What is the breadth and depth of environmental sustainability coverage in the UK construction industry by academia since the inception period of the sustainable construction guidelines?
- **RQ2:** What are the perceptions of construction managers, in both UK and Greek construction organisations, in terms of the drivers leading to the adoption of sustainable practices in their organisations and their supply chains, and how are these perceptions constructed?
- **RQ3:** How relevant is institutional theory in the context of sustainability drivers within the construction industry's supply chains?
- **RQ4:** Does the application of a carbon assessment tool in a Greek SME construction company allow for interventions in the supply chain to lower emissions?

The term 'supply chain' is deliberately left out of the first question, as the author aspired to discern from the findings of the systematic review the major areas of research in the specific industry related to sustainability. All research questions emerged from the outcome of a thorough review of existing literature, and the thesis aims to provide useful insights that will help towards a better understanding of what needs to be done for more efficient, sustainable supply chains.

3.2 Systematic Literature Review

3.2.1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)

For the first research question, the author embodies a methodological review known as systematic review. In their research, Grant and Booth (2009) provide an in-depth analysis of review types, stating that the aim of a systematic review is an ‘exhaustive and comprehensive’ search to reveal what is known while the result of such search is an analysis accompanied by a tabular format of the findings. According to Liberati et al. (2009), ‘*a systematic review attempts to collate all empirical evidence that fits pre-specified eligibility criteria to answer a specific research question*’ (p. 2). The author adopted the methods section of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) to conduct a systematic review (Shamseer et al., 2015; Liberati et al., 2009; Moher et al., 2009) and present the findings of the review (Boland et al., 2017).

Table 3-1: List of databases searched in the systematic review

Databases searched	
ScienceDirect	Emerald Insight
Scopus®	JSTOR Journals
Complementary Index	PsycINFO
Academic Search Complete	Art & Architecture Complete
Business Source Complete	British Library EThOS
Environment Complete	Computers & Applied Sciences Complete
Supplemental Index	Education Research Complete
GreenFILE	SPORTDiscus with Full Text
Directory of Open Access Journals	Oxford Scholarship Online
SwePub	IEEE Xplore Digital Library

The digital library database of the UoL was the primary source to assess searches on sustainability issues and the construction industry. This search came across an article asserting that Scopus is among those databases that provide the best range of academic journals covering research in the social sciences (Oppenheim, 2008). Given the availability of numerous bibliographic databases in the university's online search engine, they have set the search platform for this research. Table 3-1 presents the databases being searched.

3.2.1.1 Searching criteria – Decision to include or exclude articles

The first step, following the decision and selection of the themes to be searched, was to define the search inclusion and exclusion criteria. Articles that meet the following requirements were included in the collection:

- Publication language is English
- Full-text and peer-reviewed articles
- Sustainability topics related only to the UK construction industry
- Published from January 1994 to August 2018.
- Discussion of either challenges, risks, opportunities, or drivers of sustainable construction in the UK
- Meet several keyword criteria to cover a range of terms used as synonyms for construction

Exclusion criteria were as follows:

- Earlier publication year than the aforementioned period and generally not meeting any of the criteria above
- The abstract of the article is not related to the research topic
- Content does not provide the necessary information for the research topic
- Language other than English

The first search looked for the following limiters (Boolean) in the articles' titles and abstracts as well as publication years:

('sustainability' or 'sustainable' OR 'green' or 'environment*' or 'eco*' or 'energy' or 're*') AND ('construction' OR 'build*' OR 'hous*' OR 'industr*') and from 1994 to 2018.

This search returned 1,577 articles. Table 3-2 shows the searches, their criteria and the number of articles returned after each search. Twenty bibliographic databases were searched (presented in Table 3-1). From the third search onwards, some of these databases ceased to provide any results because of the additional criteria applied, which eventually no articles in their collection met. Therefore, these databases were exhausted.

Table 3-2: Search, criteria and number of extracted articles

	Criterion 1	Criterion 2	Number of articles extracted
First search	(‘sustainability’ OR ‘sustainable’ OR ‘green’ OR ‘environment*’ OR ‘eco*’ OR ‘energy’ OR ‘re*’) AND (‘construction’ OR ‘build*’ OR ‘hous*’ OR ‘industr*’)	Publication year from 1994 to 2018	1577
Second search	Full text online	Peer-reviewed Journals	402
Third search	Academic journals		379
Fourth search	Limit by subject		146
Fifth search (manual)	Removal of duplicates		102
Sixth search (manual)	UK-focused articles		29

Table 3-3 shows the limitation of search by subject (fourth search). Table 17-1 in Appendix I provides the number of articles extracted from those databases at the end of the second search.

Table 3-3: Limitation of search by subject (fourth search)

Limit by Subject	
sustainability	sustainable development
sustainable buildings	urban planning
sustainable building	sustainable construction
renewable energy sources	stakeholders
construction industry	supply chain management
environmental sciences	social responsibility
supply chain	construction
ecological impact	green buildings
public policy	stakeholder analysis
strategic planning	built environment
policy development	sustainability assessment
building materials	buildings
carbon dioxide	case studies

The PRISMA flowchart (Figure 3.1) demonstrates the search process from start to finish. A total of 29 articles fulfilled all criteria, and the results and analysis of the systematic review are presented in Chapter 4.

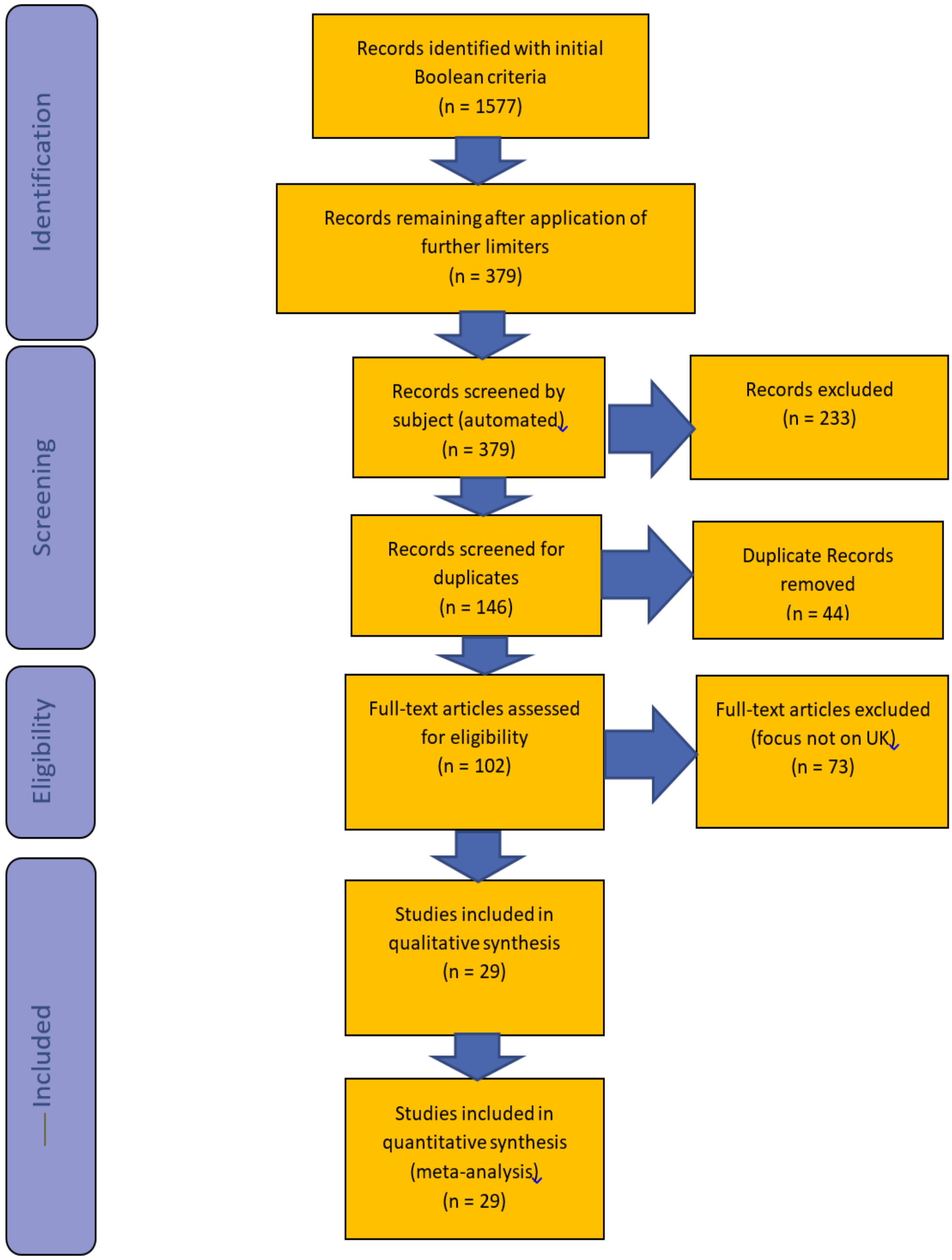


Figure 3.1: PRISMA flow chart

3.3 Qualitative Research

3.3.1 Constructivist research philosophy

The study adopts the phenomenological constructivist research philosophy to explore the views of construction managers on sustainability practices within their organisations, and specifically on the environmental aspect of the triple bottom line framework. Setting the institutional pressures stemming from institutional theory as the theoretical framework of the study, the author uses exploratory research design and inductive reasoning to develop a deep understanding and knowledge of the phenomenon to try to explain it. According to Merriam and Caffarella (in Amineh and Asl, 2015, p. 1), '*the constructivist stance maintains that learning is a process of constructing meaning; it is how people make sense of their experience*'. Similarly, Honebein (in Adom et al., 2016, p. 2) '*describes the constructivism philosophical paradigm as an approach that asserts that people construct their own understanding and knowledge of the world through experiencing things and reflecting on those experiences*'. When CSR became a research topic of interest, researchers had adopted a positivist stance in assessing whether its implementation was successful (Samy and Robertson, 2017), and the authors claim, '*It is now recognized that CSR research cannot rely on positivist mainstream quantitative techniques which are too shallow to address its complexity, as they can rely on: too few variables; do not put studied phenomena in their proper context and natural setting; and ignore the human aspects, individual personalities, collective consciousness and roles that govern CSR practices*' (p. 437). A constructivist stance prevailed during the last decade and provided a better explanation of reality (Samy and Robertson, 2017). Constructivism incorporates qualitative research using open-ended questions while focusing on a single concept (Dudovskiy, n.d.). During the research process, the researcher uses hermeneutic competence to construct meaningful assertions or create a 'pattern of meanings' or even generate theory (Creswell, 2003). This is the meaning of inductive reasoning, which is based on learning stemming from experience and is eventually a bottom–up approach (Lodico et al., 2010). The data analysis practices are detailed in section 3.3.4.

3.3.2 Purposive sampling

This analysis aims to investigate the drivers of sustainable practices among UK and Greek construction companies as perceived by professionals whose primary work responsibilities are tightly related and fall within the context of sustainability principles. This study reveals and examines the challenges faced by those organisations in adopting sustainable practices, in addition to the risks and opportunities of construction companies stemming from climate change.

A qualitative approach was selected to investigate the perceptions of construction managers related to sustainability, as the researcher aimed to achieve in-depth understanding rather than adopt a quantitative approach, which would provide breadth (Patton, 2002). The research instrument was semi-structured interviews, which can provide rich information from managers in different construction companies in the UK and in Greece while covering organisations of different sizes in both countries.

According to Trochim (2000), non-probability sampling is divided into convenient and purposive categories. Although convenience sampling can be used in both qualitative and quantitative research, purposive sampling is suitable only in qualitative research. Etikan et al. (2016) claims that when the researcher selects his/her subjects (interviewees) based on their close proximity to him/her, this denotes convenience sampling, but on the contrary, in purposive sampling, the subjects fulfil specific requirements that the researcher has in mind. As the term indicates, in purposive sampling, there must be a specific purpose in the mind of the researcher or predefined criteria as to the appropriate participants for the study. Therefore, it is not a matter of an individual's availability but rather an individual's 'fit' to the study according to predefined criteria. Palys (2008) advances this view by stating, '*Research participants are not always created equal – one well-placed articulate informant will often advance the research far better than any randomly chosen sample of 50 – and researchers need to take this into account in choosing a sample*' (p. 697). This leads to the homogeneous purposive sampling, which is a focused approach reducing variation (Patton, 2015).

3.3.2.1 Homogeneous, exponential discriminative snowball and mixed purposive sampling

Gentles et al. (2015) assert that '*Patton's typology of purposeful sampling strategies has been so highly influential as to dominate the general qualitative methods literature on sampling, with many well-known methods authors citing his descriptions*' (p. 1777).

In a **homogenous purposive** sample, the participants have a common set of characteristics; therefore, there is a small variance among them. In this study, those who participated in the interviews are all managers of construction projects and/or executives in construction companies with duties relevant to the sustainable development of their respective organisations. To reduce bias in the selection of participants, the researcher decided to combine the homogenous sampling approach with snowball or chain purposive sampling (Patton, 2015). In snowball purposive sampling, the researcher seeks a referral from people who know people, who know people, and so on, which explains the reason of otherwise naming it as chain referral sampling. During the referral process, Naderifar et al. (2017) claim that '*the risk of bias is low when the population is homogeneous in terms of the target characteristic under question*' (p. 2). It is therefore assumed that using a combination of these two purposive strategies, bias is reduced. To do this even further in the current study, the researcher has chosen to adopt the **exponential discriminative snowball sampling**. In this type of sampling, the researcher receives multiple referrals from an individual but selects only one. The decision usually depends on the targeted objectives of the research (Dudovskiy, n.d.).

The choice of using two purposive sampling methods is addressed in Patton's (2002) typology as a combination or mixed purposeful sampling and in Benoot et al. (2016).

3.3.3 Research sample – Data saturation

As mentioned in the introduction, the research interviews were conducted in the UK and in Greece. In total, 27 professionals were interviewed, 13 of them from the UK and 14 from Greece. The research strategy has been implemented in the exact same manner in both countries, using similar procedures in executing the aforementioned approaches. The vast majority of the interviews, 24 of them, were conducted face-to-face, and three participants were interviewed through Skype, one from UK and two from Greece. All interviews were recorded, and the average duration was approximately 60 minutes. The location of the interviews varied according to the workplace of the participants. In the UK, the interviews were conducted in the cities or the surrounding areas of Liverpool – five interviews, two in Birmingham, three in Manchester and three in London. In Greece, six took place in Athens and eight in Thessaloniki. The interviews in the UK were conducted in May and June 2018, and those in Greece during July and August of the same year. More details on the sample and demographic data is presented in Chapter 5 of the thesis. Table 3-4 presents the position titles of the participants as they were provided during the interviews.

At the beginning of the interview process, it was unknown to the researcher what the sample size would be, as many leading qualitative researchers (Colaizzi, 1978; Glaser and Strauss, 1967) state that it is difficult to even approximate the sample size. As the literature on qualitative research suggests, specifically on purposive sampling, the collection of data must carry on until the participants cease to provide any new information or ideas on the topic under investigation, thus reaching *data saturation* (Patton, 2015; Teddlie and Yu, 2007; Gentles et al., 2015; Etikan et al., 2016). As Patton (1990) advocates, '*There are no rules for sample size in qualitative inquiry. Sample size depends on what you want to know, the purpose of the inquiry, what's at stake, what will be useful, what will have credibility*' (p. 184). Teddly and Yu (2007) opine that in purposive sampling, the sample size is typically small, with usually less than 30 units being sufficient, while Colaizzi (in Gentles et al., 2015) suggests that in descriptive phenomenology research tradition, which shares some similar characteristics with the constructivism research philosophy in terms of the process used to data collection, 12 units (individuals) will suffice. Polkinghorne (1989) suggests that between 5 to 25 interviews are needed to explicate the experiences. Lee et al. (2014), in their descriptive phenomenology study, used 15 interviews by employing purposive sampling in a social science research while Annansingh and Howell (2016) ran six interviews for the qualitative part of a mixed-method approach, using phenomenological constructivism in information systems research.

Table 3-4: Roles of participants

UK	Greece
Commercial Construction Manager	Business Owner – Project Manager
Construction Manager	Chief Executive Officer
Construction Programme Coordinator	Construction Operations Manager
Design and Construction Project Manager	Director of Construction
Director of Construction	Director of Project Development Department
Eco Inventory & Low Carbon Design Researcher	Head of Power Generation Projects
Head of Continuous Improvement	Landscape Engineer
Head of Sustainability	Manager of Construction Projects
Project Manager	Procurement Senior Account Manager
Project Manager – Civil Engineer	Project Manager
Senior Project Manager	Project Manager
Sustainability Officer	Project Manager
UK Head of Sustainability Delivery & Development	Project Manager
	Project Manager – Mechanical Engineer

It was therefore imperative in this thesis to seek cases where rich information could be retrieved, and if that could be achieved, then the sample size could be smaller. Incorporating the mixed purposive sampling strategy by combining exponential discriminative snowball with homogeneous sampling provided the researcher the confidence to carry on with this method. According to Teddlie and Yu (2007), homogeneous sampling achieves representativeness or comparability. Data saturation has been reached during the first 12 interviews in the UK since many of the participants had long working experiences in well-established organisations, were willing to share their knowledge with the researcher and were able to articulate their thoughts in forming their perceptions.

To conclude, in any given case, when adopting purposive sampling, the process is terminated when the key points of the issue under investigation are repeated as additional interviews are conducted. Therefore, saturation is the key element here (Vasileiou et al., 2018).

3.3.4 Data analysis - Process of analysing the interviews

3.3.4.1 Thematic analysis

As the data from the interviews was qualitative in nature and the aim of the research was to investigate participants' views towards sustainability practices within their companies, *thematic analysis* was selected to analyse the data. This method enables the researcher to increase the accuracy and validity of their analysis (Yin, 2009) by adopting a *systematic manner* in analysing data (Boyatzis, 1998). *Systematic manner* here refers to the clear stages that researchers follow in thematic data analysis. For this research, latent thematic analysis is adopted as opposed to semantic thematic analysis. This decision was made as the research has a constructive stance, and therefore, latent thematic analysis would enable the researcher to go beyond the surface and examine the deeper meanings behind ideas in seeking to answer the research questions (Patton, 2002).

For this research, Braun and Clarke's (2006) stages were used. These include the following:

1. Familiarising oneself with the data
2. Generating initial codes
3. Searching for themes
4. Reviewing themes
5. Defining and naming themes
6. Producing the report

A description of how these stages are adopted for this analysis is below:

- **Stage 1 - Familiarising oneself with the data**

It was particularly important for the researcher to become familiar with and understand the collected data as much as possible. Data was imported from interview transcripts in Microsoft

Word format to NVivo software. NVivo was used as both the data analysis software and the research data database.

The data was read several times, and upon concluding that a good understanding of it has been reached, the study moved forward to the second phase.

- **Stage 2 - Generating initial codes**

Coding the research data was undertaken using NVivo; all data were coded even if the link between them and research questions was not clear or there was no direct link. This measure was taken as Braun and Clarke (2006, p.89) note, '*You never know what might be interesting later*'!

To code the data, Corbin and Strauss's (2008) analytical strategies were applied. These strategies are listed below alongside explanations of how they were adopted in this data analysis.

1. **Asking questions:** Corbin and Strauss encourage researchers to ask questions and brainstorm when coding; they believe this would help researchers 'think out of the box'. Additionally, asking questions would also result in a better understanding of the data. As such, for this research, the researcher constantly asked himself questions such as 'Why did they say that?' 'How has A affected B?', and others. This strategy enables the researcher to not only achieve deeper understanding of the data but also gain a deeper understanding of the research population.
2. **Making comparisons:** Two methods of comparison are introduced by Corbin and Strauss (2008): constant comparisons and theoretical comparisons. These methods enable the researcher to detect hidden meanings in the data, avoid bias, gain deeper understanding of and identify possible patterns in the data. *Constant comparison* means constantly comparing each part of the dataset with the others for similarities and differences. They may have similar or different codes, but usually they belong to the same theme and highlight different aspects of each code. For this research, the researcher constantly compared the data to make sure all data coded under same theme carried similar meanings.
3. **Various meanings of a word.** Corbin and Strauss (2008) argue that when dealing with qualitative data, it should be considered that words may have different meanings, and people could potentially interpret words in various ways. As such, it is important to

consider various possible meanings behind each word or piece of data during the coding stage. For this analysis, the researcher was mindful of this issue and considered various meanings of key words. However, when the meaning was doubtful, the whole transcript was read several times to ensure complete understanding of what meaning participants intended to communicate.

These three strategies were used when coding the data. Bryman's (2016) advice was followed, namely, to keep all or some of the surrounding data with the codes, as this would assist the researcher when revising and reviewing them.

When a new code was generated, all codes were reviewed to merge similar codes, decode some sections of the data and re-code them. Additionally, if a section of data carried more than one important meaning, it was coded in various categories to ensure all aspects of data are coded. By doing this, the coding evolved during the process – this was able to happen because the pre-existing codes were not adhered to, granting the researcher flexibility to enable him to enhance the codes by constantly reviewing and revising them.

When coding the interviews, saturation was achieved after the first 12 interviews for each country. The researcher continued with an additional interview of a UK company and two more in the case of Greece; this could indicate a sufficient amount of data. However, according to Patton (2002), this can also be due to similarities between the study populations.

- **Stage 3 - Searching for themes**

To search for themes, all codes were reviewed, and where possible, the relationship between them was established. Codes which carried similar meanings were categorised together and given appropriate names. For example, all codes related to the 'cost or payback' category were grouped together under the code 'cost saving'. This process helped the researcher to identify emerging patterns and themes within the data.

Furthermore, the 'hierarchy chart' in NVivo was also used to assist the researcher in identifying themes. Mind-mapping was also applied to establish the links between the codes and potential themes. Similarly to the coding stage, themes were reviewed, merged, formed into sub-themes or discarded. It should be also noted that this process is iterative and not linear.

- **Stage 4 - Reviewing themes**

Braun and Clarke (2006, p. 87) define this stage as *"[c]hecking if the themes work in relation to the coded extracts (level 1) and the entire data set (level 2), generating a thematic 'map' of the analysis."*

These two levels are also termed 'internal homogeneity' and 'external homogeneity' by Patton (1990). At the first level, all data related to each theme are reviewed to achieve coherence. During the second level, themes are reviewed regarding the whole data set to ensure the thematic map represents the meaning in the data and the relationship between themes truly represents of the whole data set.

During the level 1 review, in this research, all quotes relating to each theme were reviewed to ensure they represented the themes' meanings and were coherent. If the themes were not strongly related to the quotes and codes, they were each reviewed again to identify whether the belonging data was incoherent or the theme was ill-defined. When the problem was identified, some themes were re-defined, merged or discarded. This process continued until a satisfactory level of coherence between themes and data was achieved.

In the level 2 review, all themes were again reviewed, but this time, this occurred in relation to the whole data set. All codes were reviewed, and all data were checked to ensure every aspect was coded correctly. Additionally, all themes were reviewed to ensure they reflected the meaning in the data. This stage was finalised when the researcher was satisfied with the themes. Otherwise, as Braun and Clarke (2006) state, this stage can be potentially infinite.

- **Stage 5 - Defining and naming themes**

At this stage, all themes have been refined, and the aspect of data they represented has been clarified. It is essential to ensure themes are not too complex here and also that the data is coherent and represents the themes (Braun & Clarke, 2006).

In this work, the researcher reviewed the data associated with each theme to identify quotes which could communicate the meaning of the themes and highlight the link between various themes. All themes and associated quotes were reviewed and revised to maximise coherency.

After the first set of interviews were analysed and themes identified, more interviews were conducted, focusing on the themes from the first set of interviews to investigate the participants' perceptions regarding those areas in more detail. These interviews were then merged with the first set of interviews and analysed following the above stages.

- **Stage 6 - Producing the report**

To write the report, all quotes were reviewed to ensure they represented accurate meaning behind each theme. The report aims to answer two of the research questions and also highlights important aspects of the data. The findings and discussion are presented in Chapter 5 of the thesis.

3.3.5 Trustworthiness of the research (validity and reliability)

Any type of research has to be conducted with rigour to maintain its utility. In quantitative research, focus is given to the reliability and validity of the research method(s) being applied. This had been the case for qualitative research as well until the seminal works of Guba (1981) and Guba and Lincoln (1981). In their work, the authors proposed that qualitative methods should not be assessed in a similar manner as quantitative ones, meaning that the terms 'reliability' and 'validity' are not suitable to the latter; instead, they have proposed for qualitative methods to be evaluated according to the concept of trustworthiness. Trustworthiness is comprised of four dimensions (Guba and Lincoln, 1994), which are

- transferability, which assesses external validity (and generalisability)
- credibility, which assesses internal validity
- dependability, which corresponds to reliability
- confirmability, which assesses objectivity

According to Morse et al. (2002), very few qualitative researchers from the United States are referring to reliability and validity in their research any longer. It seems that this trend is being followed in Great Britain and Europe now; thus, a permanent turn is occurring in qualitative methods by adapting to the trustworthiness criteria.

In this thesis, trustworthiness criteria have been met through the researcher's actions throughout the study. In this self-assessment exercise to demonstrate which actions or steps of the research process fulfilled trustworthiness criteria, the researcher considers all three different methods being used: the systematic literature review, the qualitative study through interviews and the case study with the application of SCEnAT, which is discussed in the next section.

3.3.5.1 Transferability

In terms of the transferability criterion, the approach taken towards the search criteria in the systematic literature review can be transferred to other studies. The phenomenological constructivist philosophy, as the researcher's stance in observing a social phenomenon, can be transferred, and in general, the research strategy is transferable to other studies. The coding methods during the thematic analysis are also transferable. The application process of the carbon assessment tool can be transferred although for the calculation of the emissions of different processes, the data inputs will be different. To the researcher's knowledge, no prior study has investigated environmental sustainability practices and perceptions with the same philosophical stance not only in the UK but globally. The approach can be transferred to examine the construction industry of any specific country or even any other industry. In fact, this is one of the theoretical contributions of this thesis. The methodological approach used in this thesis is relevant to the criteria proposed by Aguinis and Solarino (2019) in what they call '*empirical replication*', meaning that the findings of this study are reproducible.

3.3.5.2 Credibility

The credibility criterion, which corresponds to internal validity in quantitative research, assesses whether the outcomes of the study are credible or otherwise believable. The mixed purposive sampling has significantly reduced researcher's bias. The homogeneous sampling ensured that only participants with high relevancy with the objectives of the study would be interviewed. Similarly, bias has been greatly diminished during the systematic review process. The emergence of themes during the thematic analysis adds further to the credibility of the research. To conduct interviews, ethical approval was sought, and received, from the University of Liverpool. Risk assessment for the study was also presented and approved by the university's ethics committee. The SCEnAT input collection form has been developed by University of Sheffield researchers and tested in previous research studies.

3.3.5.3 Dependability

The dependability of the study's outcomes has been strengthened by receiving recommendations and valuable, constructive feedback during the journey of this thesis. The participant's information sheet and consent form (in Appendix K) ensure the anonymity of the participants and the confidentiality of personal data. The information-rich transcripts of the interviews are securely stored in the university's central storage facilities.

3.3.5.4 Confirmability

In terms of confirmability, other researchers can reinforce the results if they adopt the same philosophical thinking. Before coding the data to identify emerging themes, the participants verified the transcribed interviews. The interviews were taken from two different groups in terms of nationality, thus enhancing objectivity. An additional factor that increased confirmability is the use of the Ecoinvent database, an external database which provided carbon emission values during the application of SCEnAT. External databases were used in the Systematic Literature Review (SLR) process. The results of this study can be reproducible under the '*exact replication*' classification of Aguinis and Solarino (2019).

3.4 Case study

As mentioned at the beginning of the chapter, this thesis incorporates three methodological approaches. The third approach is a case study of an SME construction company in Greece, where the researcher, in order to answer the last research question, employs the Supply Chain Environmental Analysis Tool (SCEnAT). A detailed analysis of SCEnAT was given in section 2.8 of the literature chapter. The case study company is an SME construction and infrastructure company specialising in asphalt production and is mainly involved in state projects and less in private ones. Its headquarters is located in Thessaloniki and has two operational sites, one in Kassandra and one in Pella. It has approximately 200 employees, many of whom are on seasonal basis. More details of the case study organisation are provided in Chapter 6. In this section, the author concentrates on the data collection methods and requirements.

3.4.1 Methods of data collection

According to Eisenhardt (1989), a typical case study will combine data sources and collection methods, and collected data will be both quantitative and qualitative. Six sources that are most commonly used to collect data for case studies are: documents, archives, direct observations, participant observations and physical artefacts (Yin, 2009). Documents may include reports, contracts and internal documents; archives may include records, charts and maps; interviews can be structured, unstructured or semi-structured; and direct observation takes place on site visits.

According to Baxter and Jack (2008), bringing together and analysing data from several sources and combining qualitative and quantitative data make for a holistic comprehension of the subject being researched and strengthen the outcome of the study.

The data collection methods used in this research included several company documents and older records that helped identify the key supply chain partners of the organisation, unstructured interviews with the CEO of the company and the operations manager to clarify and understand key internal and external organisational activities, and finally, data was collected by observing the product development process (asphalt). To use the SCEnAT software, data from the Ecoinvent database was also gathered.

3.4.1.1 Primary and secondary data requirements

The researcher gathered primary and secondary data during three visits at the company's premises. One visit at the company's headquarters, and one in each of the two sites, at Pella and Kassandra. One of data collection methods were through a data collection sheet, which has been specifically created for that purpose by the developers of the software at Sheffield University and which has been used in previous studies. The data collection sheet can be seen in Appendix J. Company documents from which data was collected include bills, contracts, lists of inventory lists, production maps, purchasing orders and various additional reports. The availability of data to the researcher was limited to only one fiscal year. Only data from the 2013 production year was available to the researcher. The Chief Executive Officer of the company was interviewed at the headquarters initially, and this being one of the twenty-seven interviews of this study. To improve insights and clarify some of the provided documentation, the researcher interviewed the operations manager in each of the two company's production sites. As the best way of clarifying documents and data received, interviews were both informal and unstructured, and co-occurred with direct on-site observations. Rather than recording interviews in full, the data-collection sheet was utilised. Table 3-5 presents the data requirements needed as primary input for SCEnAT.

The Ecoinvent database provided the secondary data concerning the life-cycle inventory. The importance of LCI databases in conducting life cycle analysis (LCA) studies was stressed by Suh et al. (2013), who said they helped resource-reductions, as well as the time required to conduct the study, and a comprehensive database could make the study more comparable.

Table 3-5: Case company's input-data requirements

Quantity and Unit Price	Supply Chain Network Information	Additional information
Raw materials (gravel, sand, etc.)	Upstream suppliers	Process inventory
Electricity	Midstream processes	Life cycle inventory
Gasoline and diesel	Downstream distribution	Data for production processes
Water	Reverse logistics (if any)	Disposal of generated waste

Other LCI databases are available, but Ecoinvent is comprehensive. Suh et al. (2013) compared a variety of available databases and highlighted the superiority of the Ecoinvent database over the rest. He specifically pointed to more than 4500 unit-process data sets of the said database compared with only 600 in the U.S. respective LCI database. The last update of the database took place in 2018 and according to Ecoinvent (2018) there are over 14700 LCI data sets in its current version3.5.

3.4.2 Validity of data and limitations

The section above described how data has been collected using several collection methods. According to Saunders et al. (2009), combining data collected from several sources allows triangulation, which provides a multi-dimensional view of the issue being researched, enabling data to be validated. Incorporating a combination of approaches and triangulating, is of extreme significance in the case of logistics studies, because of the greater insights it provides compared with a single method (Mangan et al., 2004). That, however, does not change the fact that the data, though validated, produce results that remain specific to the company. This is among the limitations of the case-study method since, according to Yin (2009), the outcomes of the study are not constituting a basis for generalisation to a wider-context, as for example an industrial sector. Results from our research are specific to the product, the supply chain, and the company and have limited applicability to other companies or products. The methodological approach is reproducible (Aguinis and Solarino, 2019) and transferable (Guba and Lincoln, 1994), however.

3.5 Ethical considerations of the research

The researcher was obligated to follow the necessary steps and take the appropriate measures to ensure that this study adheres to the ethical instructions of the University of Macedonia and to the Code of Ethics of the University of Liverpool. The researcher has undergone an obligatory research training course of the University of Liverpool and was successful during the required examination. To undertake research involving human participants, ethics approval was required, sought and received upon the successful application from the University of Liverpool's ethics committee (Appendix K). The ethics committee has approved the interview guide, the Participants' Information Sheet, and the Participants' Consent Form (Appendix K).

In the latter two documents, it is stated specifically that participants in this research are volunteers. Even if participants agreed to take part, they could, at a later stage, withdraw at any time without explanation, and any data gathered up to that point would have been destroyed.

To ensure confidentiality, research participants will not have their names recorded next to direct quotes or other data. Instead, their role/position will be recorded but not their agency/department or any other identifying information. All data are stored securely on password-locked University of Liverpool servers and will be destroyed five years after the completion of this study. Where material provided is used in subsequent reports or publications, a pseudonym will be used. Participants have given their consent by signing on the form prior to interviews.

4 Systematic Literature Review of Environmental Sustainability in UK Construction Industry

4.1 Introduction

In this chapter, the researcher aims to address the first research question of the study, by examining the breadth and depth of the environmental sustainability coverage in the UK construction industry by academia since the inception period of the sustainable construction guidelines. The findings of the systematic review are presented in a tabular format, followed by a discussion attempting to purvey the answer to the research question.

4.2 Findings of the Systematic Literature Review

In section 3.2 it has been demonstrated how the use of the PRISMA method resulted in the final list of twenty-nine articles which have met the criteria been set. As it was explained, the focus of the systematic review was only on the UK construction industry. It needs to be admitted at this point, that the initial intention of the researcher was to expand the systematic review to the Greek construction industry as well. A preliminary search using the exact same criteria as for the UK industry has returned zero results. When reducing the criteria down to only "energy" and/or "renewable" without the "construction" criterion, a number of articles had been extracted but were then rejected in order to align with the searching process and the findings of the UK industry. Nevertheless, some of these articles referring to Greece were utilised in the discussion of chapter five.

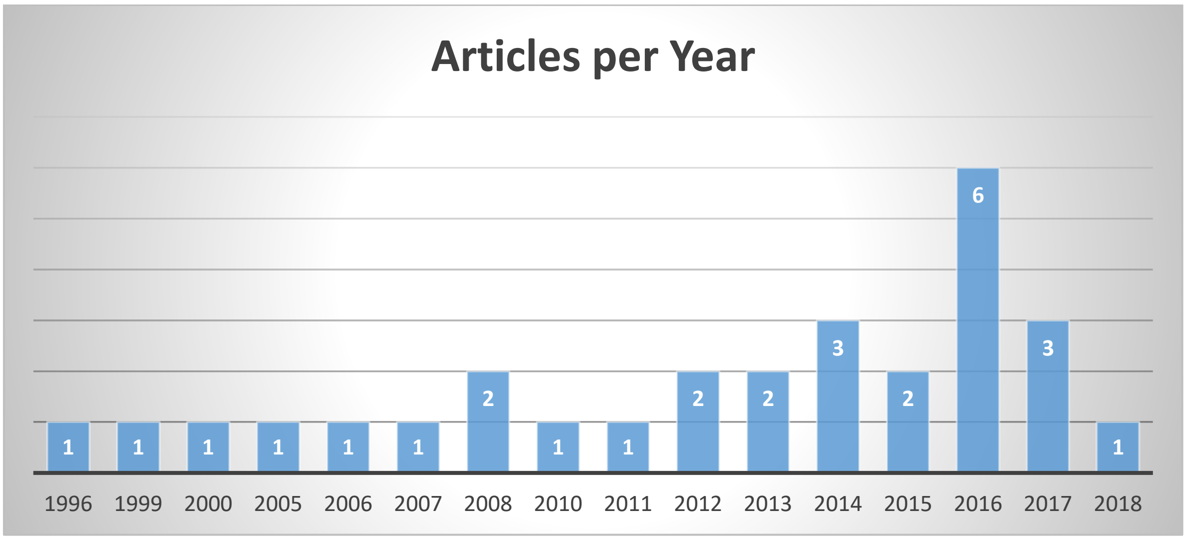


Figure 4.1: Related articles published per year

The searching criteria (section 3.2.1.1 and table 3-2) applied in twenty bibliographical databases, yielded twenty-nine peer-reviewed academic articles published in twenty different scientific journals covering areas such as construction, engineering, business management, energy, but are all related more or less to sustainable development. The inception period of construction sustainability guidelines in UK took place in 1994 and the first published article was related to teaching and educating the generations of that era on renewable energy in buildings. Figure 4.1 shows the aricles published per year, while the journals and the number of articles published by each journal are shown on figure 4.2. From that, one can see that two journals, *Construction Innovation* and *Construction Management and Economics*, account for almost a third of the total published articles, which fulfil the search criteria.

Figure 4.2: Number of articles per journal title

The collected articles from the systematic review cover a wide range of topics related to sustainable development. Almost half of the articles are focusing on green buildings and energy. In these articles, emphasis is given to building materials which in essence relate to energy savings, their recyclability and reusability. Green rating of buildings has also attracted attention from researchers, as well procurement issues such as near sourcing and green suppliers. Table 4-1 provides an overview of each paper and a brief reason for its inclusion.

Table 4-1: Journal articles identified by the SLR

No.	Author (year)	Title	Overview	Key reasons for inclusion
1.	**Xia *et al.* (2018)**	Conceptualising the state of the art of corporate social responsibility (CSR) in the construction industry and its nexus to sustainable development.	A review of CSR context to construction industry was carried out through systematic reviews of current literature.	The study contributes to social aspect of sustainability, which is related to research topic.
2.	**Darko *et al.* (2017)**	Drivers for green building: A review of empirical studies	A literature review of drivers of green buildings was explored based on leading countries involved in green building.	An empirical analysis that presented the findings of previous studies. This can be utilised for comparison with other related literature.
3.	**Doan *et al.* (2017)**	A critical comparison of green building rating systems	A systematic review of current articles comparing sustainability assessment methods such as LEED, BREEAM, CASBEE and other green rating systems.	The article provides discussion points for answering questions related to sustainable practices in construction operations.
4.	**Shan *et al.* (2017)**	A global review of sustainable construction project financing: Policies, practices, and research efforts	A systematic review of sustainable construction project financing. Focal point about financing construction projects.	The article is supporting the research topic. It provides discussion points for answering questions related to the perceived drivers/challenges of sustainable construction.
5.	**Brooks & Rich (2016)**	Sustainable construction and socio-technical transitions in London's mega-projects	A study that explores how sustainable procurement is deployed in the construction industry as well as identifying barriers to sustainable procurement of materials - cost and risk.	The article provides an insight to green practice such as sustainable procurement of construction materials. The views of procurement professionals and decision makers on construction projects were reported.
6.	**Darko & Chan (2016)**	Critical analysis of green building research trend in construction journals	An overview of green building trends in terms of number of publications, geographical contributions and topics covered.	The study focuses on the articles in green buildings from 1990 to 2015. This improves the research systematic review efficiency.

7. Higham *et al.* (2016)	Sustainability and investment appraisal for housing regeneration projects	Use of assessment framework to evaluate UK sustainable construction practice through quantitative approach.	The research provides points of arguments regarding the dimensions of which sustainability is been assessed in the UK construction setting.
8. Gottsche *et al.* (2016)	Assessing the impact of energy management initiatives on the energy usage during the construction phase of an educational building project in Ireland.	A study reporting energy reduction practices in UK building projects, resulting to savings in costs, improvement in resource efficiency, and reduction in environmental impacts.	Article addressed positive outcomes of TBL dimensions as a result of sustainable practice (energy tracking) in UK construction industry.
9. Murtagh *et al.* (2016)	The relationship between motivations of architectural designers and environmentally sustainable construction design	Psychological factors such as motivation, awareness of work's impact on others and so on, were identified as a driver for contributing to sustainable practice in construction industry.	Some of the major social drivers of sustainable practice in UK construction industries were revealed.
10. Hopkins (2016)	Barriers to adoption of campus green building policies	Environmental impacts derived from lack of sustainable adoption was presented in the article. The common challenges faced were reported and possible solutions were offered.	The article addresses the environmental dimension of the TBL which is critical to the research topic.
11. Petri *et al.* (2015)	A semantic service-oriented platform for energy efficient buildings	The research introduces a service-oriented platform that integrates access to sustainability resources to address the lack of awareness and positive energy practice. It educates and encourages building managers to implement energy efficient optimisation plans by engaging construction stakeholders with sustainability practices	Relatable to research questions by revealing opportunity for addressing barriers of sustainability practices in construction industry.
12. Dadhich *et al.* (2015)	Developing sustainable supply chains in the UK construction industry: A case study	Research looked into identifying emission 'hotspots' across the lifecycle of a plasterboard supply chain	Supply chain accounts for part of the lifecycle in construction project. The article revealed the depth of sustainability practices in UK construction projects.

13.	**Wang *et al.* (2014)**	Use of wood in green building: A study of expert perspectives from the UK	Article exploring the use of green construction materials such as wood as a means of sustainable practice. Result showed that due to levels of sustainability education among stakeholders, there are varied acceptances to the proposed concept.	"Major drivers promoting wood as a sustainable solution for green buildings in the UK construction sector include legislation, environmental awareness, attitudes and traditions, market and competition, promotion and communication, and technology and know-how".
14.	**Opoku & Ahmed (2014)**	Embracing sustainability practices in UK construction organizations: Challenges facing intra-organizational leadership	Research on challenges faced by leaders in construction industry when adopting sustainable practices.	Emphasis on the challenges faced by construction managers and decision makers on implementing sustainable construction practice was explored.
15.	**Ogunbiyi *et al.* (2014)**	An empirical study of the impact of lean construction techniques on sustainable construction in the UK	A research addressing the impact of lean construction technique revealed positive effect to TBL dimension of sustainability	The TBL dimensions were addressed and the study revealed various benefits as a result of sustainable practice implementation.
16.	**Akadiri & Fadiya (2013)**	Empirical analysis of the determinants of environmentally sustainable practices in the UK construction industry	Determinants of environmentally sustainable practice in UK construction industry were revealed to include top management commitment, government regulations and construction stakeholder pressures.	The article provides information on the drivers of sustainable practice in construction settings.
17.	**Florez *et al.* (2013)**	Measuring sustainability perceptions of construction materials	Sustainable construction materials were identified as a means for decreasing the negative impact on the environment. Different views were examined due to varied opinions on sustainability in general.	The article enhances the perceptions of decision makers on construction materials, addressing the environmental, social and economic benefits to the construction industry.
18.	**Akadiri & Olomolaiye (2012)**	Development of sustainable assessment criteria for building materials selection	Selection of sustainable building materials can be difficult due to ambiguity amongst construction professionals. Assessment criteria, along with methods and processes to execute the assessment was explored.	The article reported challenges to sustainability practice in the construction industry.

19.	**Renukappa *et al.* (2012)**	A critical reflection on sustainability within the UK industrial sectors	A research exploring the perception in multiple industrial sectors (construction industry included) on the concept of sustainability. Findings included variability in perceptions at different industries. Most importantly, proposed solution included an industry wide awareness raising programme.	The article provided a glimpse of sustainability drivers/challenges perceived in related organisations, including the construction industry.
20.	**Rodriguez-Melo & Mansouri (2011)**	Stakeholder engagement: Defining strategic advantage for sustainable construction	A study depicting the relationship between stakeholder engagement and a prosperous sustainable practice. This was perceived as both a driving factor and hindrance to sustainable practice in UK construction industries.	An insight to stakeholder behaviour was revealed.
21.	**Essex & Whelan (2010)**	Increasing local reuse of building materials	Reuse of surplus construction product creates opportunities of employment and training in new skills.	Based on social benefit of sustainability
22.	**Ravetz (2008)**	Resource flow analysis for sustainable construction: Metrics for an integrated supply chain approach	Sustainability metrics and benchmarks are used in determining sustainability impact across the construction supply chain. The study presented the available metrics in UK construction industry	This study reveals the depth at which sustainability practices are being honoured in the UK construction settings.
23.	**Taylor & Wilkie (2008)**	Briefing: Sustainable construction through improved information flows	Transparency of construction process, from design to use, was presented and segments which prevent sustainability practices were identified and explored to recommend potential solutions for future reference.	Research revealed the barriers to sustainable design in the UK.
24.	**Bosher *et al.* (2007)**	Realising a resilient and sustainable built environment: Towards a strategic agenda for the United Kingdom.	Research calls for immediate integration among construction stakeholders	Research revealed the barriers to sustainable design in the UK.
25.	**Shiers *et al.* (2006)**	Sustainable construction: The development and evaluation of an environmental profiling system for construction products	The article explores why environmental tools are less implemented in construction projects. The findings of the article exclaimed disparities between project specification and practices.	These are potential challenges faced by construction professionals

26. Myers (2005)	A review of construction companies' attitudes to sustainability	Research explores the perception of construction organisations towards sustainability practice	Potential drivers/challenges to sustainable construction was revealed.
27. Bartlett & Howard (2000)	Informing the decision makers on the cost and value of green building	The article explored the potential payback value of a green building.	Most emphasis is placed on the economic dimension of the TBL.
28. Raynsford (1999)	The UK's approach to sustainable development in construction	Emphasis of UK's approach to sustainable construction during the late 1990s was revealed.	Findings from the article will contribute to discussion about shift from previous practice to current perceived practice in the construction settings.
29. Pitts (1996)	Teaching renewable energy and the sustainable building network	Emphasis on the impact of educating current generation about sustainable building networks is promoted in the article.	Article revealed that sustainability awareness has always been a challenge in the construction industry. Therefore, constant drive to improve awareness is a discussion topic.

4.3 Breadth and depth of sustainability coverage

To understand sustainability in the context of construction in the UK demands understanding how industries achieve sustainability in their actions and practices, their methods, the tools and techniques at their disposal, and their understanding of what sustainability is. A wide-ranging analysis of issues concerning sustainability in construction in the UK (see the authors listed in table 4-1) indicates that the subject has been fairly researched. Examination of conventional construction's social and environmental approaches suggests that the subject has been of great interest both to practitioners and to researchers. Subjects researched have included sustainable construction's practice by way of articles in journals in an attempt to raise awareness of sustainability in practitioners throughout construction's supply chain (Higham and Thomson, 2015; Hopkins, 2016). The importance of increasing awareness lies in the benchmark it provides for all parties. Interviews conducted showed how scattered opinion on the subject was, suggesting that the concept is not uniformly understood, a suggestion that others support (Petri et al., 2015; Opoku and Ahmed 2014; Higham and Thomson 2015; Hopkins 2016).

It also proved to be the case that, when a building's sustainability was mentioned, it was only to address operational life when the building project began (Berardi, 2013). As 70% of extracted resources find their way into buildings, there was an obvious need to raise awareness of sustainable construction practice and to extend evaluation to cover the entire life of the project if building materials were to be available to future generations. Higham and Thomson (2015) called for a shift in mind-set on sustainability.

It is also evident from the extracted resources that there is lack of a supply chain perspective among the focus of the studies and their findings. Only those articles or findings referring to procurement have a direct relevance to supply chain management.

4.3.1 Environmentally sustainable construction

The literature suggests that the UK construction industry's primary agenda is to reduce the emission of greenhouse gases (Essex and Whelan, 2010). Florez et al. (2013) and Wang et al. (2014) researched use of sustainable materials and reported that recycling and reuse can reduce waste from building projects and also reduce the total of landfill waste, leading to negligible environmental impact throughout the building's life and a reduction in carbon emissions. This correlates with results of interviews. The predominant response was to invest in technologies for reducing emissions, suggesting that UK construction is currently pursuing technological advances. The sustainable acquisition of construction materials led to the reporting of sustainable procurement as a way of achieving sustainability (Brooks and Rich 2016). All interview participants said that their companies understood sustainable procurement's value and this can be correlated with replies to questions on organisational culture and departmental practice, in that organisations in which the CEO and executive management were committed to sustainable practice were likely to implement sustainable procurement. Panwar et al. (2006) were of the opinion that organisation size was significant here and Brooks and Rich (2016) said that different organisations understood sustainable procurement in different ways. This explains why interviews received a variety of responses, where some interview participants came from large enterprises and some from SMEs. Cost, existing methods and short-term planning were shown to be constraints on sustainable supply chain management. Construction projects are reported by Bosher et al. (2007) to be fragmented, raising possible barriers to sustainable practice.

Ogunbiyi et al. (2014), coming into agreement with Dainty and Brooke (2004), reported integrating lean construction practice as a sustainable construction issue and listed the benefits it could bring in reducing construction waste, value generation, increased productivity, better health and safety, and an encouraging working environment. Taylor and Wilkie (2008) reported similar findings and suggested that additional benefits included better information flow, reduced risks, the maintenance of future value and lower operating costs.

Gottsche et al. (2016) reported UK construction's energy management initiatives and mentioned lower CO_2 emissions because good site management practice reduced consumption of electricity. Technology was reported as facilitating sustainable construction. Shan et al. (2017) researched financing of sustainable projects and showed that banks and government schemes were investing more in sustainable development projects. In 2012, the UK set up the world's first green investment bank to support sustainable and green projects (Shan et al., 2017). A system for rating sustainable buildings included the UK's renowned Building Research Establishment Environmental Assessment Method (BREEAM) and this and LEED (Leadership in Energy and Environmental Design) were cited frequently in the literature as a way of assessing UK construction's sustainability (Potbhare et al., 2009; Doan et al., 2017).

4.3.2 Socially sustainable construction

How organisations are influenced by the environment and how they affect each other has been the subject of study for some time. There has not been widespread reporting of how UK construction as an industry demonstrates social responsibility, but it is nevertheless a growing factor among practitioners (Edum-Fotwe and Price 2009). Xia et al. (2017) showed that more attention is being given to CSR (corporate social responsibility) as part of sustainable construction projects and reported the high level of attention given to workers health and safety. Construction is both, competitive and labour-intensive, so that there is a high exposure to accidents, but CSR mitigates those concerns because discourse on public health, skills and education, social justice, working conditions, human rights, workplace safety and equal opportunity combine to require companies to show a high level of legal, ethical and discretionary involvement and stakeholders are closely involved in projects (Xia et al. 2017; Renukappa et al., 2012).

5 Perceptions on Drivers of Environmentally Sustainable Supply Chains in the Construction Industry

5.1 Introduction

This chapter aims to provide answers to the second and third research questions, which are stated as follows:

- **RQ2:** What are the perceptions of construction managers in both UK and Greek construction organisations in terms of drivers leading to the adoption of sustainable practices in their organisations and their supply chains, and how are these perceptions constructed?
- **RQ3:** How relevant is institutional theory in the context of sustainability drivers within construction industry's supply chains?

As discussed in section 3.3 of the methodology chapter, the researcher embraces qualitative data collection methods and, consequently, uses qualitative data analysis to provide answers to the above questions. Initially, the discussion is fed by a demographic analysis of the research participants, followed by findings and a critical discussion on each thematic topic as they have emerged from the analysis of the interview data. The chapter concludes by proposing a theoretical framework developed based on the research findings and their analysis.

5.2 Sample demographics

Table 3-4 in Chapter 3 demonstrated the current position of each participant within their organisation. The sample provides information-rich cases (Patton, 2015; Aguinis and Solarino, 2019) where the researcher can draw insightful information from, and this is attributed to the fact that participant selection was based on the homogeneous purposive sampling approach. Figure 5.1 below shows participants' years of employment in their organisation.

Twenty-seven interviews were conducted with professionals coming from 27 different construction companies. Thirteen of those companies are UK-based, and 14 are in Greece. The adoption of exponential discriminative snowball sampling aided the researcher in participant selection due to the opportunity offered by the method to have a choice of multiple referrals. This opportunity of choice materialised in the selection of companies of different sizes.

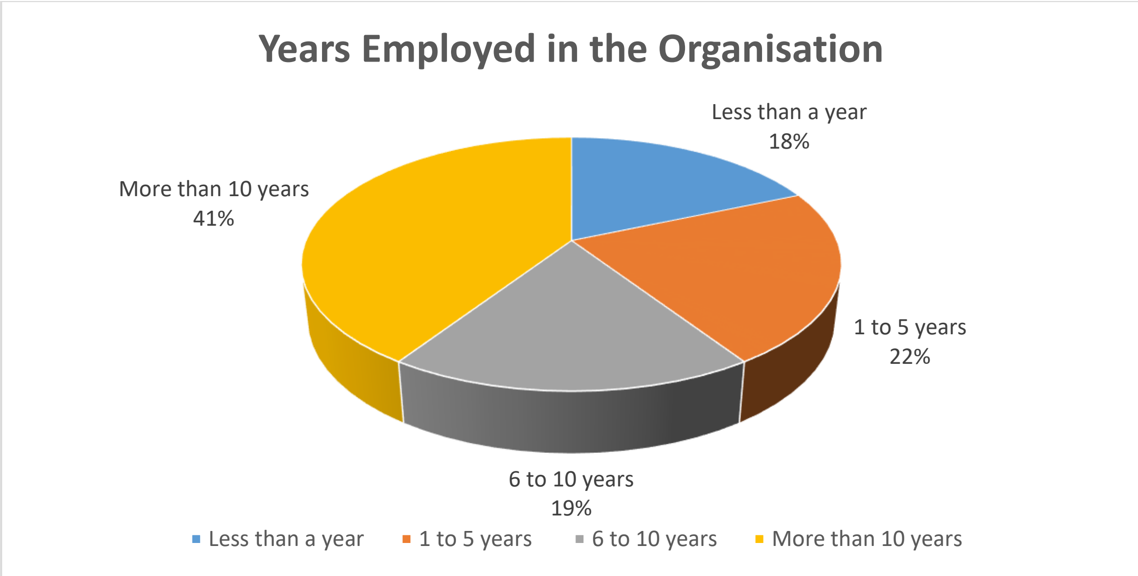


Figure 5.1: Years of employment in the organisation

Aguinis and Solarino (2019) characterise some individuals as elite informants, meaning they can provide information through interviews considered to be of great value to the researcher and cannot be gathered elsewhere. In this study, the perception of the researcher is that within the sample, there were many individuals in both countries who can be defined as elite informants. From Table 3-4 in Chapter 3, one can see that based on their role title, a few individuals stand out; for example, the title of UK Head of Sustainability Delivery & Development is indeed a signal for an information-rich individual, especially when that person is employed in one of the top five construction companies in the world. Figure 5.1 shows that 41% of the participants have more than 10 years of experience in the same organisation, which can be interpreted as having a high level of understanding and knowledge of their organisations' practices and strategies. On the contrary, 40% of the participants are working for five or less years in their organisations, which, for some of them at least being new in the work marketplace, can be assumed that their perceptions on environmental sustainability issues have not been heavily influenced by their companies' practices yet.

Figure 5.2 shows the size of the organisations where participants are employed. Half of the companies have a headcount of more than 250 employees (51.85%), and the other half consists of SMEs (29.63%) and small companies (18.52%). According to the European Commission (2018), an organisation with a headcount of more than 250 and a turnover of more than 50 million euros is considered a large organisation. A headcount of 250 or less with a turnover of equal or less than 50 million euros is considered as SME while organisations with less than 50 employees and a turnover of equal or less than 2 million euros are characterised as small.

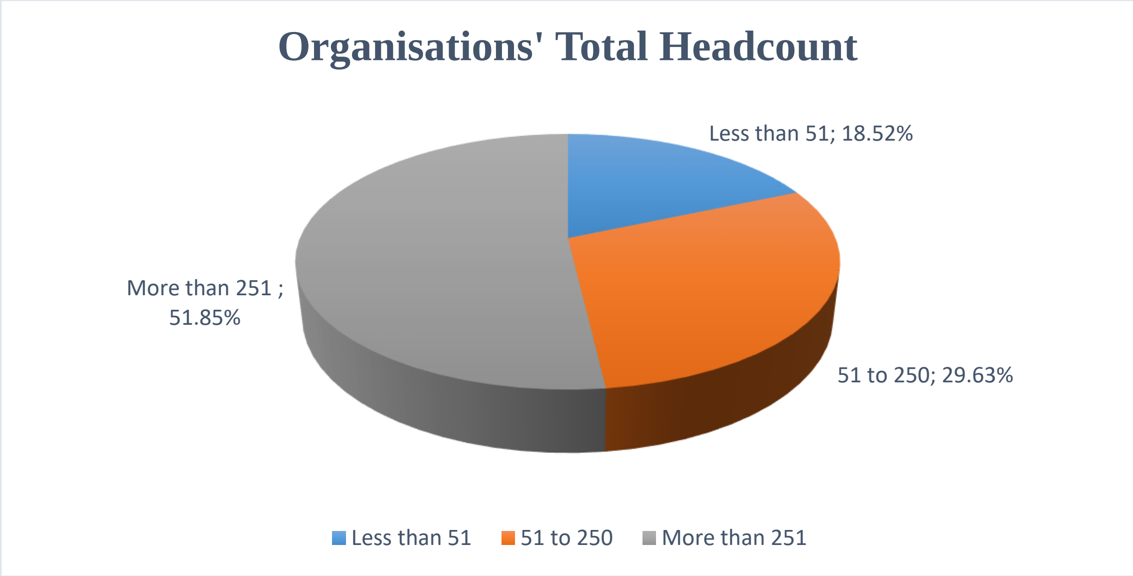
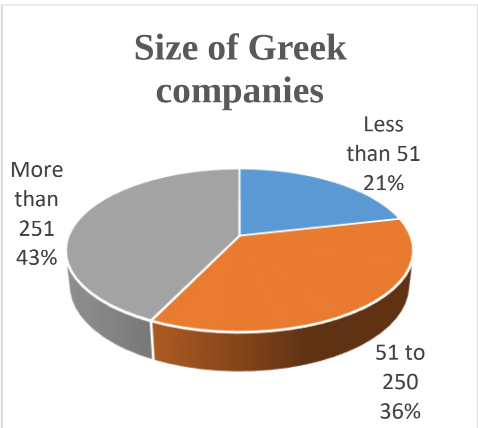


Figure 5.2: Size of organisations

Figure 5.3 presents the allocation of the companies, in terms of their size, from the two investigated countries. The two distinct samples are not identical, but they are similar in distribution.



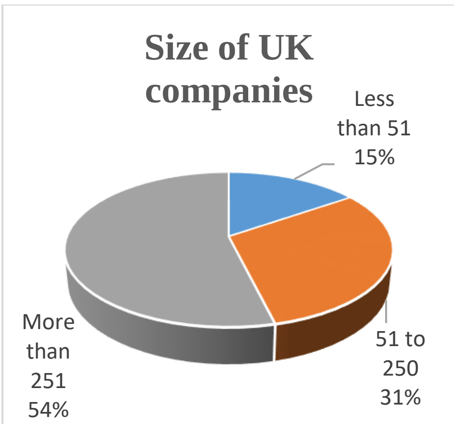


Figure 5.3: Size of organisations per country

Table 5-1 shows the actual number of companies represented by the participants according to size and classified by country of origin. It needs to be mentioned here that there is only one company in the sample, located in Greece, which is a branch of a multinational organisation operating in Greece.

Table 5-1: Number of companies represented

Number of companies represented in the sample		
Company size	**United Kingdom**	**Greece**
More than 250	7	6
Between 51 and 250	4	5
50 or less	2	3
Total	**13**	**14**
Grand total	27	

The total sample consists of 11 multinational (MNCs) and 16 local organisations. Of the 16 local organisations, 9 of them are considered SMEs while the other 7 are large companies employing more than 250 people each. Figure 5.4 shows the market penetration of these organisations.

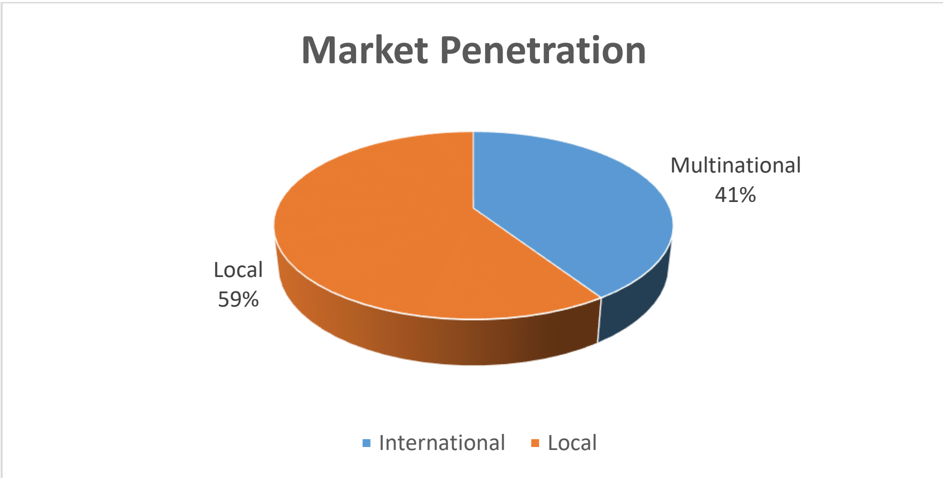


Figure 5.4: Market penetration

The distribution of companies in terms of status is demonstrated in Table 5-2 below, with more detail regarding the country of origin.

Table 5-2: Multinational versus local companies

Classification of organisations			
	UK	**Greece**	**Total**
Multinational	6	5	**11**
Local	7	9	**16**

Stocks of 12 of the companies represented in the sample are traded in either the London or Athens stock exchange market. Eight of them are British and four are Greek. Overall, the status of the majority of the represented organisations in the sample gives an added confidence to the researcher to build upon the information gathered from interviews.

5.3 Sustainability drivers

5.3.1 Findings

The participants were asked to express their perceptions on sustainability drivers as they experience them from the organisations they operate in. A latent thematic analysis was selected to analyse the data as explained in the methodology chapter. According to Yin (2009), this approach increases the accuracy and validity of the analysis. Figure 5.5 is an output from NVivo, the software used for coding and analysing data in this thesis. It shows the main themes that emerged from the participants' responses. It can be seen that '**financial dimension**' and '**Government/EU regulations**' were the two predominant perceived factors for their organisations to engage in sustainability-related actions. Two indicative excerpts from the participants on cost savings are as follows:

The main thing is that we have to be in line with certain government directives, and also in effect, essentially, being sustainable, usually reduces costs anyway, so that's, that's quite a major contributing factor if I'm honest with you. [Part 8]

It's because of all this green environmental movement and everything else now, we're reconstituting the material we remove from site, which does make sense. Obviously, it's a cheaper, it's cheaper anyway. It's cheaper for the end user. If we take material away to a tip, and then have to bring material from another source in, it's more expensive for us, more expensive for the client, and more expensive for the end user. [Part 11]

Meanwhile, one of the participants discussing regulations asserted, *There is more than one drivers in terms of sustainability, so bear in mind that the construction industry, including rail and infrastructure, is a highly, highly regulated industry, which means one of the big drivers is government and the relevant legislation which is supported by the government. That means that even if the company is not willing to comply, you will have to comply with certain regulations to be able to operate in the industry.* [Part 3]

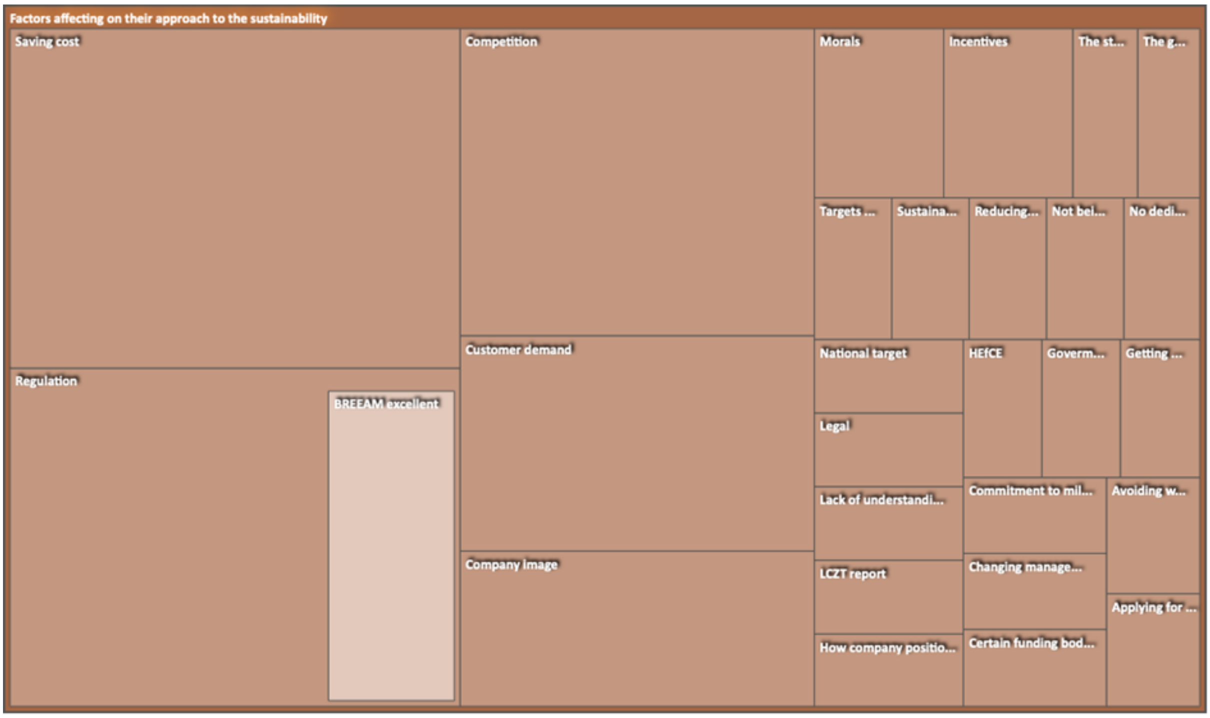


Figure 5.5: Themes emerging for sustainability drivers

The financial factor seemed to be more of a concern to UK participants than those from Greece although it was declared as a factor by many Greek interviewees. Government regulations were the most influential driver among the Greek participants.

The next two drivers perceived as strong influencers for adopting sustainable practices were fear of '**competitors**' and '**client requirements**'. Competition received slightly less attention from Greek participants, but they showed slightly higher consideration for customer requirements. Some excerpts on the issue are the following:

[W]hen it comes to getting like projects from maybe public sector and there are certain things you have to demonstrate how we look after our sustainability. That's major, when we want to win work from a client, that's a major, what can I say, a major requirement that we demonstrate how sustainable we are, so what we do. [Part 2]

If the estate and the buildings aren't able to cope with things like climate change, people will go to companies that are better able to do it. [Part 1]

[I]t takes you ahead if you can prove to the client that you're working for, you get repeat business. So that's why I would say that the investment is then turning to profit. [Part 15]

Participants were very aware of client requirements especially when the customer is a public organisation, and sometimes the responses integrated these two factors, competitors being the other one. Some indicative responses on customers were as follows:

[A] lot of our clients will have certain standards that they want to meet or BREEAM achievement levels that they want to set. We have a lot of clients which will state how much local investment they want. They'll set kind of specific targets, but that would depend very much on who the client is, but generally we have a baseline standard within the company that we meet. [Part 9]

[B]ut to be honest, there's a lot of work that you will not win if you are not, if we're not proving that we look into sustainability. [Part 21]

The next important driver, which influences decisions on sustainability practices, is perceived to be '**organisational reputation**'. Participants from both countries were equally concerned on the specific issue. It is worth noticing, though, that organisational image is very closely related to social sustainability, as one of the participants commented,

[S]ustainability from our perspective, it's much more about promoting ourselves as a good local partner. So by not wasting the energy we do that, but by all the social impacts and working with the local community and doing work experience placements and looking at local suppliers, we focus much more on that. We deliver benefits to the local community. [Part 4]

The above statement pays attention to the local communities and local suppliers, where the latter has a positive environmental effect as well.

The last two factors perceived to be major drivers for sustainability actions of their organisations are '**executive management support**' and '**pressures from external bodies**'. Two indicative comments, one of each factor, were the following:

[T]here aren't many things we can do on a construction project regarding sustainability if it's not supported from above. [Part 19]

We have to deal with oppositions and resistance from the local community when we plan to build on public land which cause delays due to negotiations. They want to be assured that all environmental measures need to be adhered to. [Part 17]

Of these two factors, the former received more attention from Greek participants while the latter had the fewest references from the participants of both countries. Executive management support refers to the stance of top executives towards sustainability and the initiatives they take for its fruition. The external stakeholders may be partners, suppliers, communities, financial creditors, non-governmental organisations, associations and others.

5.3.2 Emergent themes

Thematic analysis of the participants' perceptions generated seven themes, which are considered as the most compelling factors for their organisations to engage in sustainable practices. Existing literature supports the views of the participants. The author examines the coverage of each factor/driver as a contributing influencer of environmental sustainability.

- **Financial dimension**. In the construction industry literature, the vast majority of the authors referring to cost savings are focusing on building materials and energy efficiency technologies used in buildings. Nevertheless, it is a common belief that excluding initial investment costs in green technologies, benefits accrue thereafter (Green et al., 1998). Green supply chains can produce cost saving (Bag, 2013; Singh and Gupta, 2014), anticipation of greater benefits (Delai and Takahashi, 2013; Al Khidir and Zailani, 2009), and they can be realised when applying a holistic life cycle approach (Kylili and Fokaides, 2017) or improved energy efficiency measures (Marchi and Zanoni, 2017).
- **Government/EU regulations**. They are the driving force in adopting sustainable practices in all industries and the most common construct of theoretical frameworks in the literature. Companies need to conform to regulations if they operate within a regulated industry, such as construction. Organisations are affected by international regulations if they wish to operate abroad (Singh and Gupta, 2014) regardless of the local legislation. Therefore, regulations are exerting pressures to all industries (Naidoo and Gasparatos, 2018; Silvestre et al., 2018; Yin et al., 2018), especially on industries with pressures on carbon emissions reduction (Hoejmose et al., 2012).
- **Competitors**. According to Gilbert (2001, p. 26), '*Competitiveness is the ability to produce, distribute and provide products and services for the open market in competition with others*'. The fear of the organisations that their competitors might be promoting themselves as sustainability-conscious and that they may be left behind is of great concern to the participants. Competitive advantage could be gained (Saha and Darnton, 2005) with practices such as green procurement and low emissions production, and recyclable products could make a difference in the market (Silvestre et al., 2018; Wu et al., 2012).

- **Client requirements**. As the public becomes more aware of the negative effects brought by climate change, it becomes more demanding as a means of self-protection (Mudgal et al., 2010; Silvestre et al., 2018) and demand for green products is increasing, thus adding pressure to organisations (Huang, 2012). It seems that this pressure will increase in the future (Gonzalez et al., 2008) as the effects of climate change become more visible, causing organisations to take the sustainability issue much more seriously.
- **Organisational reputation**. This factor is linked closely with the previous one, as no company would like to be characterised as an environmental polluter by the public. According to Singh and Gupta (2014) negative publicity is possible because of the lack of environmental policies. As organisations would make any efforts to avoid destroying their image, they will have to adopt sustainable practices (Wood, 2010; Asif et al., 2013).
- **Executive management support**. Engaging in sustainable practices should be a corporate strategy and supported by upper management (Chu et al., 2017; Dong, 2008; Daily and Huang, 2001; Thong et al., 1996) if they are to be successful as asserted by Lee (2008), Zhu et al. (2008), Hu and Hsu (2010) and Hsu and Hu (2008). Lack of management support and delays in adopting green practices are characterised as a barrier (Yin et al., 2018).
- **Pressures from other external bodies**. There are different forms of additional stakeholders exerting pressure to organisations (Silvestre et al., 2018; Heravi et al., 2015a; Zutshi and Sohal, 2004b). Pressures may be coming from NGOs (Seuring, 2013), from communities (Al Khidir and Zailani, 2009; Lee and Kim, 2009) and from integration with green suppliers (Vachon and Klassen, 2006) while lack of expressed interest from stakeholders is considered a barrier to the adoption of sustainable practices (Yin et al., 2018).

Figure 5.6 demonstrates the drivers of sustainability as they emerged from the interviews of the 27 participants.

Figure 5.6: Sustainability drivers

5.3.3 Institutional theory and the drivers of sustainability

The seven drivers leading construction firms towards sustainable practices can be classified as external and internal drivers or as endogenous and exogenous drivers (Silvestre et al., 2018). Endogenous drivers in this study are two factors: the financial dimension and executive management support. Exogenous drivers are government regulations, competitors, client requirements, organisational reputation and pressures from external bodies. Silvestre et al. (2018) provided three categories of exogenous drivers, which are regulations, social values and norms (for example, stakeholder pressures) and market pressures, which include suppliers, consumers, competitors, shareholders and others.

The interest in this part of the thesis is to investigate whether the emerged drivers of sustainability can be explained within the context of institutional theory, and in particular, the institutional pressures. Kauppi (2013) performed a systematic review to find the extent to which institutional theory has been utilised in research studies focusing on operations and supply chain management. The review examined a selected number of journals in the focal area, which are regarded high-quality publications, and returned 18 articles in total, a relatively small number considering the wide interest and popularity of the field. Six of these were on green supply chain management, five on e-tool adoption, and seven more in dispersed areas within the focused field. In all studies, results have shown that various pressures through the supply chain have a significant contribution towards firms' engagement in sustainable practices, but more studies are needed for the pressures to have an impact on organisations (Kauppi, 2013).

Thus, drawing on institutional theory, which is discussed in detail in section 2.3, the researcher categorised the seven emergent drivers according to institutional pressures, which are coercive, normative and mimetic pressures.

- **Coercive isomorphism** stems from exerted pressures by other organisations such as governments and are imposed to a company because of the form of dependency that exists between them. Thus, in this research, the **government regulations** driver falls into coercive pressure. This is supported by Hanim et al. (2012), who discuss government regulations and incentives as an effective institutional driver for organisations to adopting eco-designs for improving environmental performance. Dubey et al. (2015) also claim the effectiveness of institutional pressures on organisations, indicating government regulations as a main factor. Zhu and Sarkis (2006) and Wu et al. (2012) published similar findings, while Lu et al. (2018) call them dual pressures, referring to both, domestic and overseas institutional pressures.
- **Normative isomorphism** is achieved when a firm abides with norms, standards set by other groups or external bodies such as professional or industry associations. In other words, the firm conforms to professional or industry standards. Three of the emerged drivers in this study are classified as normative pressures, client requirements, external bodies' pressures, and organisational reputation. Saeed et al. (2018) asserts that normative pressures were found to have a greater significance than coercive or mimetic pressures on green supply chain management practices. In support of **client requirements**, according to Chu et al. (2017, p. 4), 'demand from customers shapes a core normative pressure', finding in agreement Ye et al. (2013) and Zhu and Sarkis (2007) among others, who hold the same view. Client awareness and client demand have been identified as major factors towards sustainability in the UK construction industry (Pitt et al., 2009), confirming Abidin and Pasquire (2005), who argued the importance of the client in the construction industry. **External bodies**, such as industrial associations, suppliers, communities, consumer associations and so forth, are exerting great pressures on

organisations. External bodies' pressures, as a driver for sustainable practices within the context of institutional theory, are supported by Hanim et al. (2012) discussing customer associations, Saeed et al. (2018) and Roszkowska-Menkes and Aluchna (2017) referring to non-governmental organisations while supplier pressures are also thought as strong influencers (Silvestre et al., 2018; Dubey et al., 2015; Kauppi, 2013). These pressures, besides the regulatory ones, are also leading to eco-innovations (Garcia-Granero et al., 2018). **Organisational reputation** is another normative pressure, specifically in the eyes of the consumers. Social influences shape the actions of a firm to gain legitimacy and acceptance from society (Chu et al., 2018; Berrone et al., 2013; DiMaggio and Powell, 1983). The company's green image is an important factor for a company; thus, being environmentally responsible attracts positive attention (Mathiyazhagan et al., 2014). Agan et al. (2013) argue that image, brand, and reputation are very significant drivers to enforce companies to implement sustainable production practices. Ye et al. (2013) opine that all companies are subject to expectations of their external stakeholders; therefore, reputation is of imperative importance.

- **Mimetic isomorphism** occurs when a firm is mimicking another successful firm, usually a competitor, or benchmarks what is thought to be best practice. The **competitors** driver that emerged in this study is classified as a mimetic pressure. Companies fear that their competitors are ahead in terms of environmental actions, and this pressure forces them to follow. This type of pressure has a significantly positive effect towards engagement in sustainable practices (Chu et al., 2018; Dai et al., 2015; Dubey et al., 2015; Sarkis et al., 2011). Cai and Li (2018) have shown that pressure from competitors, in their study of driving factors in adopting eco-innovation, is the leading force for companies to get engaged. There is another study, though, on institutional pressures' effect among drivers of green supply chain management and sustainable practices (Wu et al., 2012), which provides a contradictory view. In that study, pressure from competitors had no influence at all on these two variables; in other words, the mimetic pressure here has either no effect or exactly the opposite of what was found in other studies. The explanation given was that this occurred because of the shift nowadays, where supply chains, instead of individual organisations, compete against one another.

Up to this point, five of the seven drivers were associated according to their 'fit' with the three types of institutional pressures. The last two drivers, the financial dimension and executive management support, cannot be associated a priori with any of the three categories of isomorphism. This study has unveiled their presence within the construction industry organisations and their supply chains and has identified, from the interviews, a slight indication of a relationship between the financial dimension and a coercive and a normative pressure, but not a direct causal link. The following discussion provides a clearer view of the last two drivers.

Executive management support has been the focal point of investigation in numerous studies, labelled as either leadership, or top, senior or upper management, and was found to be of significant importance towards sustainable efforts as previously discussed in this section. If executive management intends to support sustainable practices within an organisation and its supply chain, the intentions are initiated by one or a combination of institutional pressures. Those pressures might be coming from competition (mimetic), thus causing upper management to decide to engage in benchmarking, or they might stem from clients' or customers' (normative) demands or from anywhere else. Based on the interviews, the researcher did not spot a clear indication of a direct causal link between executive management support and a specific institutional pressure. The exact same issue has attracted the attention of few other researchers who, by drawing on institutional theory, had the opportunity to provide some evidence with quantitative analysis methods. For example, Chu et al. (2017), investigating the impact of institutional pressures on GSCM and company's performance, found that executive management support for environmentally sustainable SC is statistically important. Their results have also indicated that coercive pressure, in the form of regulations, did not have positively correlate with executive support. This contradicts the findings of Zhu and Sarkis (2007), which suggested that, in relation to government-imposed environmental regulations, the coercive pressure affects the tactics of executive management towards green actions. Continuing with the study of Chu et al. (2017), further findings revealed that normative (clients) and mimetic (competitors) pressures are highly correlated with the support provided by executive management to greening the firm's supply chain. In another large-scale study, Ye et al. (2013) found that all three institutional pressures have a significant positive effect on top management's posture and firms' reverse logistics activities, specifically for product recovery, but not for product return. The role of organisational leadership has been identified as a significant factor in adopting sustainable practices within the construction industry (Opoku and Ahmed, 2013; Ofori and Toor, 2012) and within a firm's supply chain (Hervani et al., 2005).

Similar to the executive management support driver, the **financial dimension** driver cannot directly relate to a particular institutional pressure based on qualitative data although there are slight indications from the following interview excerpts:

BMS is a remote-control system that can control all the air-conditioning in 70 apartments in the site or 100 containers that we have. So for example, you can order the BMS not to, when the temperature outside is 25, that nobody can use air-conditioning. Because they open the air-condition or they open the windows, etc., so this system gives you remote control through computers etc. of the entire electricity usage system, that reports where the problem is, for the fire-protection etc., it's a centralised system. So this was requested, for example, by government to have control of it, and you can set it up to minimise the misuse of the electricity.

The above case shows a link between the coercive pressure (government intervention) and economic considerations, but that could be only because of the peculiarity of the specific firm. The case below does not clarify where the pressures are coming from, as they could be from consumers or any other stakeholders; however, they denote the presence of normative pressure. As Roszkowska-Menkes and Aluchna (2017) state, by quoting DiMaggio and Powell (1983), the three institutional pressures are in many cases intermingled, which can result to different conclusions.

[I]n supply chains, we do always focus to have local procurement where possible, even sometimes with a little bit higher cost, or have local staff hired. It reduces different kinds of costs. Transportations etc.

Lozano (2015), in his efforts to investigate the internal and external motivations leading organisations to engage in corporate social responsibility activities, identified cost reductions, and profits and growth, as two of the internal motivators. The same motivators were loaded again later on in the enhanced model of Lozano and von Haartman (2018), but this time they were grouped under the label 'economic dimension'. The economic dimension of the enhanced model showed high correlation with three other drivers of their model: stakeholder pressures, reputation and markets. Therefore, looking at it from an institutional theory perspective, the economic dimension is influenced by normative pressures. Saeed et al. (2018) argue that external (customers and suppliers) green supply chain management practices positively influence the financial performance of a firm, and so does the environmental performance of the firm. The positive effects of coercive, normative and mimetic pressures on top management posture towards reverse logistics, discussed for the previous driver above, also had a positive effect on the economic performance of the firms (Ye et al., 2013). Hojnik et al. (2018) postulate that companies may get involved in eco-innovations implementation to realise cost savings and proved that eco-innovation increases the economic performance of a company. Similarly, Cai and Li (2018) came up with the same conclusions on the eco-innovation implementation and economic performance of firm by examining the positive influence of competitive and customer pressures for eco-innovation adoption. An additional study supporting the previous two, still from an institutional theory perspective, is that of Chu et al. (2018) on third-party logistics providers in China. The financial performance of an organisation sees significant improvements by adopting green innovation because of influences from competitive and client pressures but not from regulatory pressure (Chu et al., 2018). Pitt et al. (2009), conducting a construction industry survey, assert that financial incentives and regulations are the top two factors for sustainable construction. Engagement of construction firms with non-regulatory systems bring cost savings and can accrue long-term benefits (Tam et al., 2006). Financial issues are thought as the main barrier in the construction industry from engaging in sustainability at a faster pace (Shi et al., 2013; Liu et al., 2012).

5.4 Conceptual framework

In the previous section, the researcher discussed the main findings of managers' perceptions regarding their organisations' involvement in green practices. Based on the perceptions of the participants, which formed the emergent drivers following a rigorous thematic analysis as discussed in the methodology chapter, and a thorough review of the extant literature, the researcher developed a conceptual framework that reflects the views of these professionals in the UK and Greek construction industry. This is illustrated in figure 5.7.

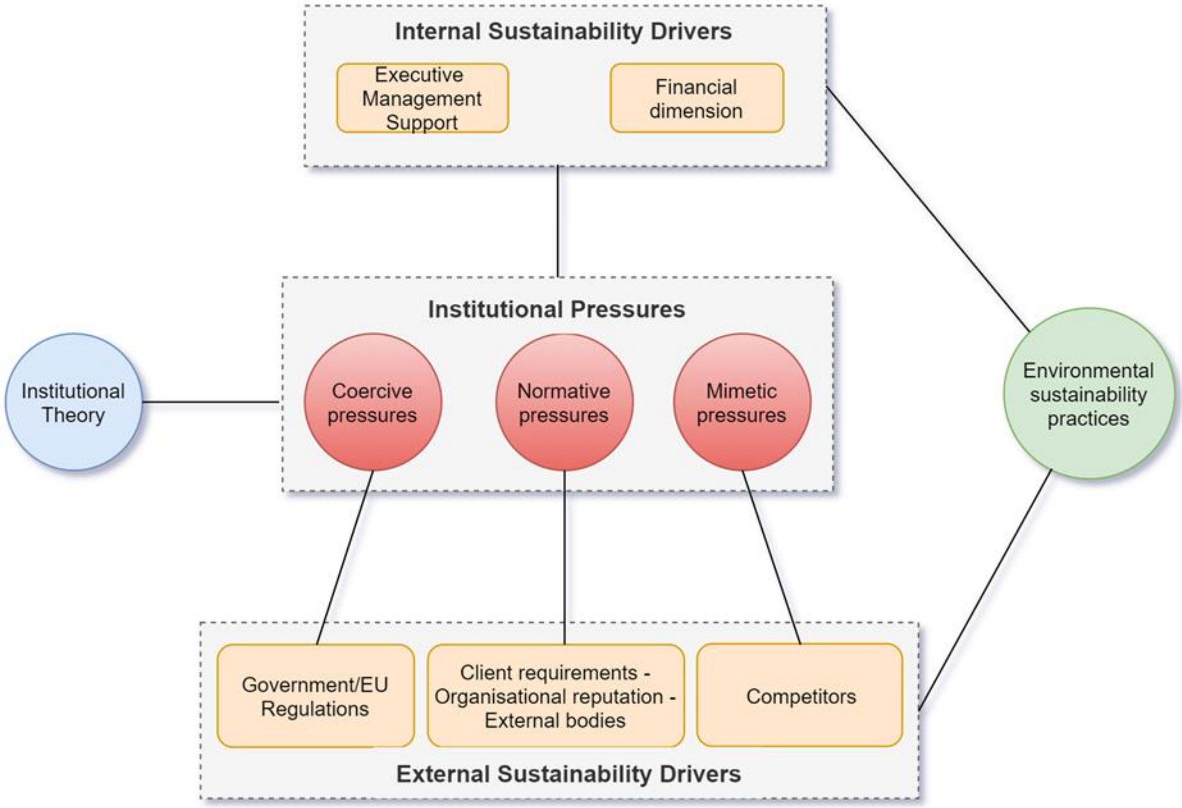


Figure 5.7: Conceptual framework

Within the framework, the institutional pressures are linked to the corresponding emergent drivers, labelled 'external sustainability drivers', while there is only one link between the institutional pressures as a whole and the two emerged drivers, labelled 'internal sustainability drivers'. The reason for the single link is the indistinct indication of the exact relationship between them although an explanation has been provided for this issue in the previous section. There was evidence of such a relation between coercive and normative pressures with the financial dimension pressure in only one of the interviews, but this was not enough to generalise it for the rest of the cases. The relationship of these two groups can be very different for any given organisation because of the uniqueness of each firm, so what applies in one does not necessarily apply to others. The assertion of Sarkis et al. (2011) that it is not clear how the interaction of those factors, endogenous and exogenous, advance green activities support this view.

Table 5-3: Pressures – Drivers – Supporting research

Institutional Pressures	Sustainability Drivers	Authors (Supporting Research)
Coercive	Government/EU Regulations	Naidoo and Gasparatos (2018), Silvestre et al. (2018), Yin et al. (2018), Lu et al. (2018), Singh and Gupta (2014), Hanim et al. (2012), Dubey et al. (2015), Zhu and Sarkis (2006), Wu et al. (2012), Hoejmose et al. (2012)
Normative	Client Requirements	Saeed et al. (2018), Chu et al. (2017), Ye et al. (2013), Zhu and Sarkis (2007), Pitt et al. (2009), Abidin and Pasquire (2005), Mudgal et al. (2010) Silvestre et al. (2018), Huang (2012), Gonzalez et al. (2008)
	Other External Bodies	Roszkowska-Menkes and Aluchna (2017), Hanim et al. (2012), Saeed et al. (2018), Silvestre et al. (2018), Dubey et al. (2015), Kauppi (2013), Silvestre et al. (2018), Zutshi and Sohal (2004b), Seuring (2013), Al Khidir and Zailani (2009), Lee and Kim (2009), Vachon and Klassen (2006), Yin et al. (2018)
	Organisational Reputation	Chu et al. (2018); Berrone et al. (2013), DiMaggio and Powell (1983), Mathiyazhagan et al. (2014), Agan et al. (2013), Ye et al. (2013), Singh and Gupta (2014), Wood (2010), Asif et al. (2013)
Mimetic	Competitors	Chu et al. (2018), Dai et al. (2015), Dubey et al. (2015), Sarkis et al., (2011), Cai and Li (2018), Wu et al., (2012), Gilbert (2001), Saha and Darnton (2005), Silvestre et al. (2018)

Combination of Institutional Pressures	Executive Management Support	Chu et al. (2017), Zhu and Sarkis (2007), Hervani et al. (2005), Ye et al. (2013), Opoku and Ahmed (2013), Ofori and Toor (2012), Dong (2008), Daily and Huang (2001), Thong et al. (1996), Lee (2008), Zhu et al. (2008), Hu and Hsu (2010), Hsu and Hu (2008), Yin et al. (2018)
	Financial Dimension	Roszkowska-Menkes and Aluchna (2017), DiMaggio and Powell (1983), Lozano (2015), Lozano and von Haartman (2018), Saeed et al. (2018), Ye et al. (2013), Hojnik et al. (2018), Cai and Li (2018), Chu et al. (2018), Shi et al. (2013), Tam et al., (2006), Pitt et al. (2009), Liu et al. (2012), Green et al. (1998), Bag (2013), Singh and Gupta (2014), Delai and Takahashi (2013), Al Khidir and Zailani (2009), Kylili and Fokaides (2017), Marchi and Zanoni (2017)

Those findings are supported by recent relevant studies in supply chain management. The result is that all seven drivers have been confirmed in different models and in a variety of industries. In the construction industry, one or more of those emerged drivers have appeared in various research studies. Table 5-3 illustrates the classification of the emerged sustainability drivers and the various research studies, which support the findings of our research. The third column of the table presents the authors whose studies were part of the discussion in the preceding section, and who have considered the corresponding drivers/factors as contributing ones towards sustainable practices in their models or analyses.

5.5 Further evidence from the qualitative research

5.5.1 Environmental policy, EMS, certified EMS

Section 5.3 dealt with the analysis of the findings regarding the perceived drivers of sustainability, and based on these, the researcher has proposed a conceptual framework (Figure 5.7). Through the interviews, the author managed to collect additional information based on facts of the represented organisations as well as other perceptions of the participants, which can contribute towards further development of the proposed framework to reflect organisational efforts and capabilities more accurately.

Participants were asked what their organisation was doing to improve sustainable practices. Most responses were about implementation of management environmental systems and environmental policies within the organisations. When few of the participants did not refer to these issues, the researcher followed up by specifically asking them the reason for not having these to obtain a complete picture of the situation. None of the five small companies (with 50 or fewer employees) of the sample had a written policy, but the two from the UK are in the planning process for theirs. The consensus was that this would be the responsibility of ownership. Obviously, there is no exerted pressure on them in terms of reporting their carbon emissions. There was, also, one Greek SME that did not have such written policy, but was planning to have one.

Twenty-one of the 27 companies have an environmental management system, and 18 have an externally certified EMS, such as ISO 14001. Three companies are in the planning stage of acquiring ISO 14001. The common explanation given was that such a certification is needed to secure more construction contracts and to be more competitive. Therefore, the decision stemmed from normative and mimetic pressures. Figure 5.8 shows the distribution of the above results.

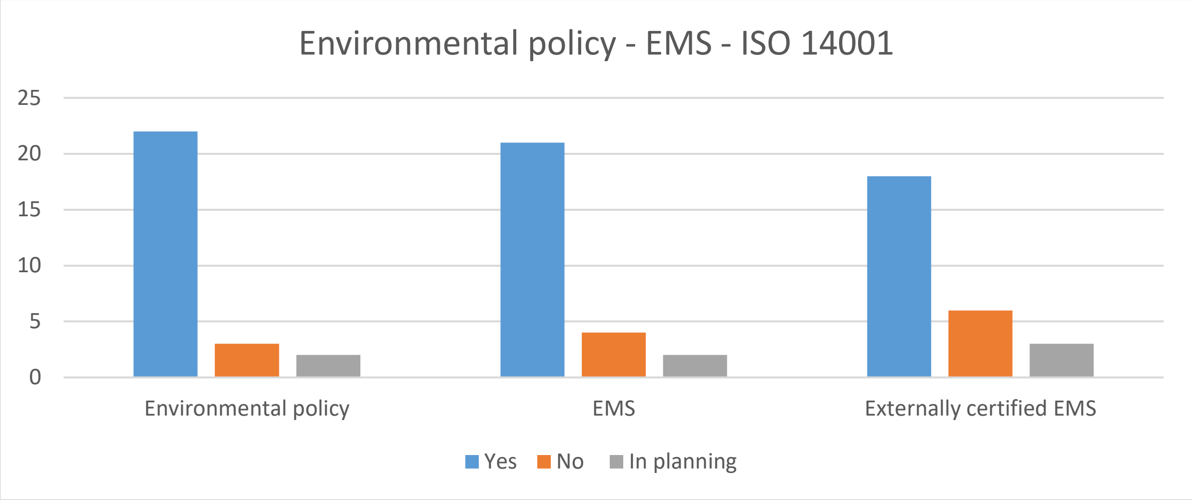


Figure 5.8: Companies with a written environmental policy, EMS or externally certified EMS

From the above, it is evident that SMEs and larger construction companies in both countries are investing in environmental management systems, which on its own is a big step forward, although the motives behind it may be different for each company.

5.5.2 Perceptions on the importance of a carbon footprint assessment software

The participants were asked about their perceptions of having a software that would assess the organisation's as well as the supply chain's carbon footprint so that it would allow for appropriate interventions to lowering them. While discussing this issue, follow-up questions referred to such software being publicly available (free of charge) and whether the government should make the software freely accessible to organisations. The following excerpts reveal some of the participant's perceptions and concerns:

I'm sure most of the companies are happy to use it, especially if it's free [. . .]. *We are not, we actually, no, we are not using a specific software. We are using Excel files to estimate the carbon emissions* [. . .]. *So that's what we use to estimate their carbon emission and when we have that, if, for example, the large carbon emission is from electricity consumption. We come up with some solution to reduce that or if it is for heating or gas consumption, we come up with solutions to reduce that. But we are not using any specific software to do that.* [Part 16]

I'm not sure how this can be implemented and whether this is going to be a one-size-fits-all solution for the various businesses. Like the rail infrastructure, for construction, also various organisations. [Part 3]

We already have like a, it's called Smart Waste, and sort of the, I don't know if it's an app or not, but it monitors what waste we're getting rid of, how much, how much carbon we're using, and it comes up on a graph and it analyses stuff. That's becoming more and more into fruition through the years, so a really sort of effective system for that would be, would definitely be taken on board if it was there. [Part 2]

[U]nder the precondition also that it is kind of directed that all the companies undergo this assessment. [Part 20]

Yes, although it is not the availability of the software that is the issue. Obtaining the right information and the complexity of using the software are the greatest challenges. For example, a simple product such as a type one aggregate would have a different carbon footprint depending on the location of the production facility to site. If you start to look at composite materials such as building cladding then these would be made of numerous components and across a whole building project could result in 100s or 1,000s of different materials. Identifying and inputting all this data into a system is very time consuming and inhibitive. [Part 5]

The government have previously developed tools to calculate carbon footprints free of charge such as the Environment Agency tool and the Highway England tool. Both of these rely on the ICE carbon data developed by Bath University that hasn't been updated in several years, although Heathrow are currently sponsoring this to be updated. Other clients such as National Grid have also developed their own tool for the contractors to use. [Part 5]

Figure 5.9 is an output from NVivo, showing the emerged themes for carbon emissions software. All twenty-seven participants recognise the importance of having such software free and publicly available by the government. The last two excerpts above came from the same participant, who is the UK Head of Sustainability Delivery & Development of a British multinational company and one of the few individuals in the sample who was aware of the existence and complexity of such tools and the availability of free-of-charge software. None of the participants seemed to be cognisant, for example, of the ISO 14064, which is the carbon footprint calculation tool in the ISO 14000 family. The researcher sees this as a major concern.

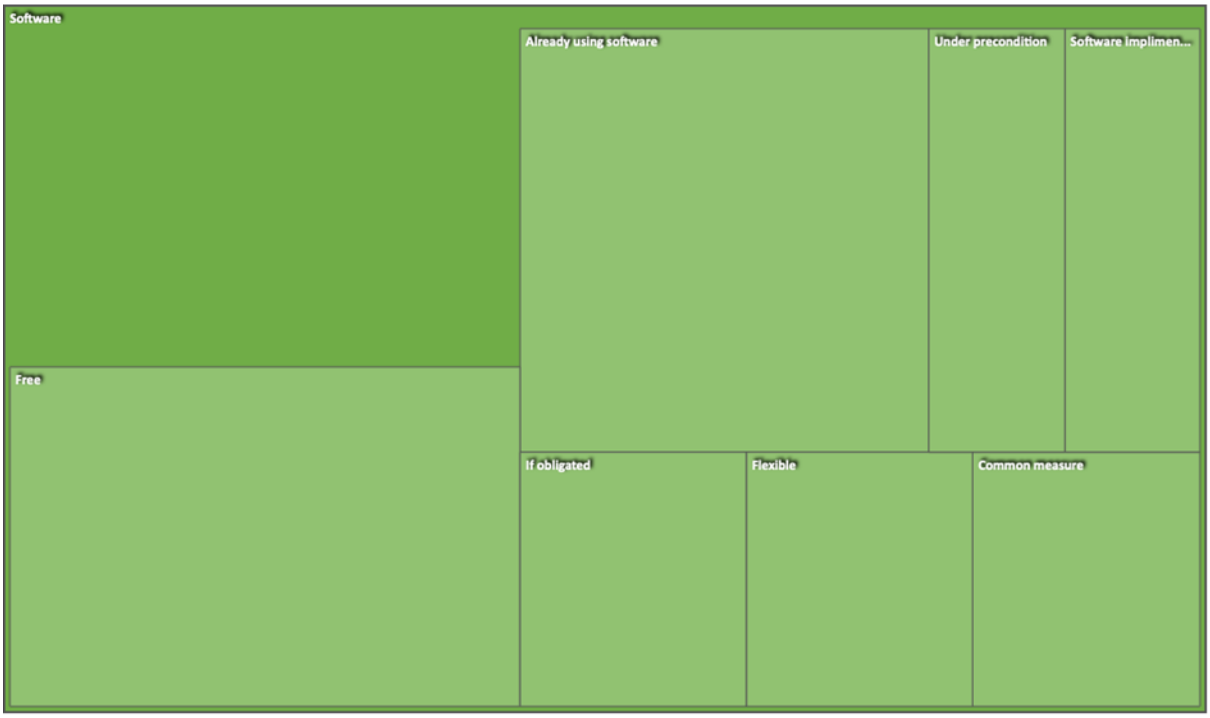


Figure 5.9: Emergent themes for carbon footprint software

Taking a constructivist approach in this research and using latent thematic analysis, the author is confident that there is generally a lack of awareness among construction project professionals regarding the availability of software that holistically evaluates the organisation's and its supply chain carbon footprint. The researcher recommends that there is an urgent need for construction companies to engage in internal education and training programmes for their employees. The willingness of these professionals is not adequate, on its own, to lead the organisations to support and conserve sustainable practices without the support of upper management.

5.6 Carbon footprint technology, education and training

Based on the additional findings regarding the use of software to obtain a broader picture of the carbon footprint of an organisation and its supply chain, two supplemental drivers emerged. First is the environmental management systems which the represented organisations have acquired in their majority, excluding the small ones with fewer than 50 employees, and second is education and training. In the following two subsections, the researcher demonstrates evidence from the extant literature in the construction industry to support this decision. In light of new knowledge, the third subsection presents a revisited conceptual framework.

5.6.1 EMS – ISO 14001

The vast majority of the represented companies have adopted performance or efficiency standards for several utilities. All large organisations have mandatory targets for electricity, gas, fuel and water usage while most of the SMEs have either mandatory or voluntarily have set targets for electricity and water usage. The large corporations and very few SMEs have mandatory standards for trade (liquid) waste generated, solid waste, contaminated waste and GHG emissions. Evidently, these companies are adhering to regulations and the BREEAM's points about waste.

Section 2.6 in the literature review provides a detailed discussion of EMS and ISO 14001. Although the acquisition of the ISO 14001 certification provides many benefits to organisations, smaller companies, while not obligated to have one, struggle with its cost. For a small company, the cost of implementing and acquiring a certification may be higher than its annual revenue (Yiridoe and Marett, 2004). Therefore, cost is a barrier for many small organisations.

Delmas and Toffel (2004) claim that ISO 14001 adoption is due to mimetic pressure, as companies cannot afford to stay behind the competition. Zutshi and Creed (2015) conducted a detailed study of environmental initiatives on a global scale, reporting benefits and challenges of EMS implementation in the construction industry at different geographies. In that study, Revell (cited in Zutshi and Creed, 2015) claimed that during the past decade, UK SME construction firms resisted the adoption of EMS, but those who did adopt one reported many benefits by engaging systematically in green practices. In the same study, Holton (cited in Zutshi and Creed, 2015) opined that barriers to acquiring such system could be overcome with upper management's dedication and offerings of training programmes to enhance skills and increase employee awareness. Zutshi and Creed (2015) assert that the environmental impact of construction undertakings could be conveyed by ISO 14001. Many companies demand suppliers or contractors (Liyin et al., 2006) to be ISO 14001 certified, especially suppliers abroad (Lee, 2015). In a finding that is more relevant to this thesis, the endogenous and exogenous drivers for such a system provide benefits to firms regardless of their magnitude or the type of industry in which they operate (Heras-Saizarbitoria et al., 2011). We can conclude that environmental management systems is an important driver towards sustainable practices.

5.6.2 Education and training as a driver

From the interview responses, there is a general ignorance of the available technology capable of capturing the carbon footprint of an organisation and its supply chain. The focus of managers in the construction industry seems restricted to the technologies around construction material and eco-designs. The findings here support the findings of the systematic literature review, which have shown that research on building issues (material and eco-design) dominates the interest in the industry, as well as the interest of academics, over that of a more holistic approach, such as supply chain considerations and interventions towards sustainable practices.

Having asked the participants what their organisations are doing to improve sustainable practices and receiving responses about EMS, the researcher continued by asking what should their organisations be doing further to improve such practices. The theme that emerged from this question was education and training:

It's a matter of education. I think it's a pure matter of education and presenting the possibility of what sustainability brings as a general well-being. [Part 21]

I am saying education is first. You know, make it tangible to the workers how this affects on local scale, on global scale, on the organisation scale, your job. [Part 8]

The procurement employees need to be aware of sustainability issues and come up with particular propositions which would change buying habits. [Part 4]

In construction industry–related research, management and training is considered as the most critical factor in the evaluation of environmental performance assessment (Tam et al., 2006) while improved education for deconstruction design (recovery of material) is a recommendation of Akinade et al. (2017). '**Education and training**' is a strong influential factor for sustainable construction (Gan et al., 2015), and according to Wong and Yip (cited in Gan et al., 2015, p. 63), '[education and training] *is rare due to heavy work commitments and lack of sponsorship from employers*'. Abidin (2010) recommends that training and education, especially for SME construction companies, would improve significantly the level of adoption of green practices. Seuring and Muller (2008) convey the need for education of purchasing employees and suppliers, and Dubey et al. (2015) stress employee awareness of the firm's environmental policy. To facilitate heavy engagement with green practices, employees must be educated and trained on the principles and approaches of sustainable construction practices (Manoliadis et al., 2006). Finally, Sfakianaki (2019), conducting a systematic literature review on the success factors of sustainability in the industry, identified 4 of 31 articles reviewed that included education and training as one of the 35 success factors in total.

It is evident that some authors, using different research instruments, such as surveys, interviews, case studies and systematic reviews, have acknowledged the important role of education and training as an influential factor for advancing awareness of the need for sustainable practices.

5.7 The conceptual framework revisited

In section 5.3, the researcher explicated the rationale underlying the development of a conceptual framework for adopting sustainable practices in the construction industry. The framework was solely based on the perceptions of the participants regarding the driving factors of their organisations to adopting sustainable practices. Further discussions with the participants revealed several organisational efforts towards this goal by taking efficiency measures to reducing energy consumption and minimising generated waste of various forms. These actions were primarily a result of the implementation of an environmental management system, and in all cases, that EMS was ISO 14001.

The interviews also revealed that very little is being done in terms of calculating the actual emissions caused by operational activities. The head of sustainability of a world-leading construction organisation clearly explained that the reason behind the decision not to calculate the carbon footprint of their operational activities any longer, while they used to in the past (section 5.4.2), was the time-consuming process. Despite this, the vast majority of the construction professionals showed unfamiliarity with carbon footprint measures. On top of all that, the participants demonstrated a **lack of supply chain perspective** in most cases, which unfortunately confirms it as one of the systematic review's conclusions. Participants talked about client demands, cost-saving internal operations, winning contracts and other issues but never referred to collaboration with supply chain partners and seeking benefits, perhaps through consolidated actions that would lead to cost savings.

In Chapter 6, the author describes the application of the SCEnAT tool on the case company for the assessment of carbon emissions in the supply chain of a specific product, the tool's ability to identify the 'hotspots' of the process and the capability to intervene in reducing the total carbon footprint of the process. Considering the results of the case study and the findings from the interviews showing high rates of EMS adoption, the previous conceptual framework is revisited to include the EMS and carbon footprint software as an additional driver, as well as the education and training factor. The author strongly believes that these two factors act as facilitating drivers or enablers for implementing green practices.

The two newly emerged drivers from this study revised the recommended conceptual framework previously developed and presented in Figure 5.7. The revised framework is presented in Figure 5.10. The word '**extended**' in the final process of the framework is used to denote and highlight the supply chain perspective, thus considering sustainable practices within not only the strict boundaries of the organisation but beyond that, including upstream and downstream operations. Achieving greater impact from supply chain practices, on both the environmental and economic performance, requires the support and collaboration of customers and suppliers (Saeed et al., 2018). Ideally, if the internal drivers could be initiated without the exerted pressures, then they are considered proactive steps (Lozano, 2015) while responding to the external drivers' pressures are reactive steps (DeSimone and Popoff, 2000).

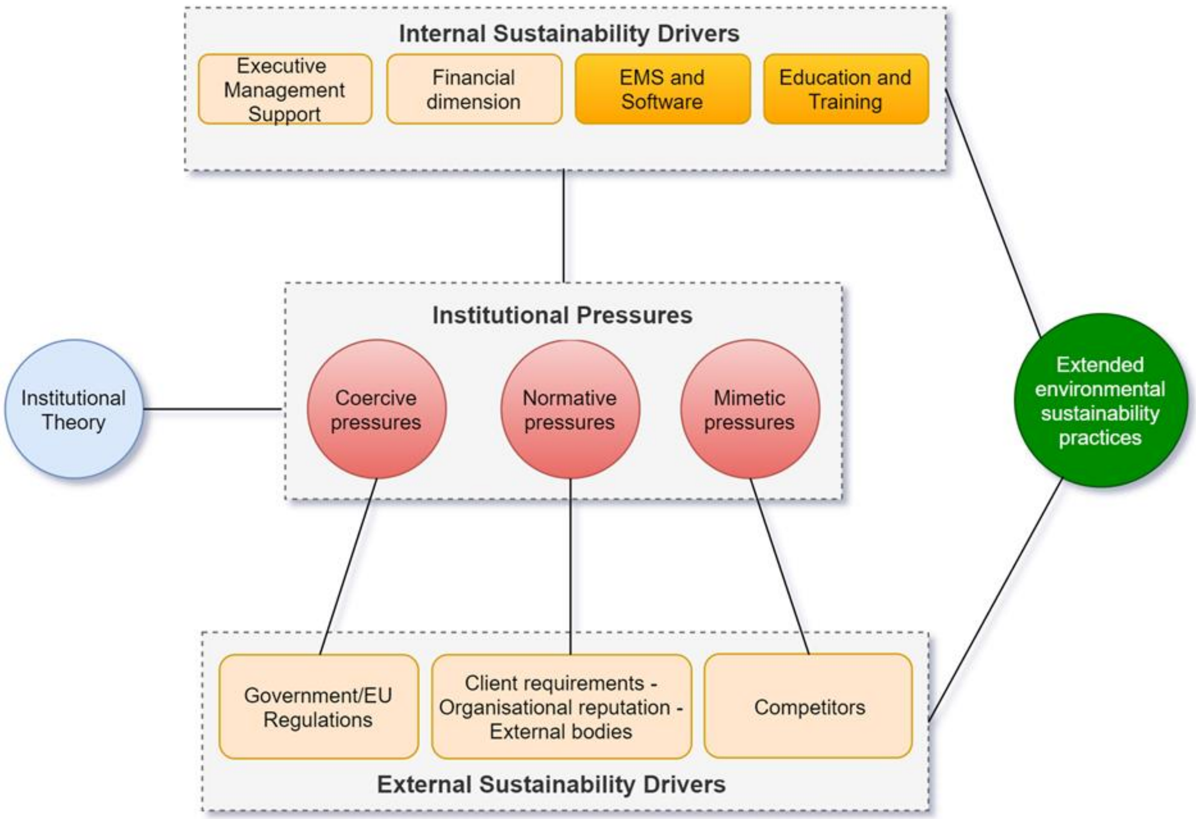


Figure 5.10: Revised conceptual framework

5.7.1 Comparison with other conceptual frameworks/models

During the discussion in this chapter and in parts of the literature review, the researcher provided insights and highlighted the main driving factors of various theoretical models and frameworks proposed by researchers, covering not only the construction but also a wider spectrum of industries and geographies. In this section, the researcher compares the proposed conceptual framework with three frameworks/models. The selection was based on the popularity of the framework for the first one, for its focus on the UK construction industry in the second framework and the institutional theory utilised in the third model.

- One of the most known and highly cited (cited 3747 times) conceptual frameworks is that of Seuring and Muller (2008). Their framework was constructed on a systematic review of 191 articles from studies around the globe and covering the whole range of economic sectors. Articles included in their review adhered to inclusion criteria, such as having a management focus, with almost half of them coming from the supply chain area and concentrated only on environmental and social sustainability. It is understood that the reviewed articles incorporated all types of research methods, from empirical to theoretical approaches. A summary of the drivers of their conceptual framework is summarised in Figure 5.11. As seen from Figure 5.11, four of the six drivers from Suering and Muller's (2008) framework are the same as those recommended in the framework of the thesis, classified as 'external sustainability drivers'. The other two, 'response to stakeholders' and 'environmental and social pressure groups', are combined into the 'external bodies' driver of our framework. Two of the internal drivers of our framework, 'EMS and software' and 'education and training', are also addressed as 'supporting factors' in Suering and Muller's (2008) framework. 'Higher costs' is classified as a barrier in their framework since sustainability practices in many occasions require an initial investment, but in our framework, not neglecting the upfront costs, we see it as a financial incentive leading to cost savings in the medium to long term.

Pressures and incentives	Number of papers ($N = 191$)
Legal demands/regulation	99
Customer demands	96
Response to stakeholders	90
Competitive advantage	71
Environmental and social pressure groups	38
Reputation loss	30

Supporting factors	Number of papers ($N = 191$)
Company-overlapping communication	89
Management systems (e.g., ISO 14001, SA 8000)	69
Monitoring, evaluation, reporting, sanctions	68
Training education of purchasing employees and suppliers	40
Integration into the corporate policy	38

Figure 5.11: Drivers in Suering and Muller's conceptual framework.

Source: Suering and Muller (2008)

The only driver that is not addressed in the compared framework is the 'executive management support' driver of our framework. The many similarities of the two frameworks:

1. Confirm the suitability of the proposed conceptual framework from a supply chain perspective.
2. Validate the research methodology and the methods utilised in this thesis to obtain the particular results.

- The only comparable framework that has been developed based exclusively on the UK construction industry is that of Akadiri and Fadiya (2013), which is one of the studies included in the systematic literature review presented in Chapter 4. The authors used a survey to test three predetermined constructs – 'top-management commitment', 'government regulations', and 'construction stakeholder pressure' – and found that all three had a positive influence on construction firms towards sustainable practices. Inherent to the 'construction stakeholder pressure' construct were pressures from clients, community, non-governmental organisations and colleagues while for the 'top-management commitment' construct, the corresponding pressures were the organisation's image and the strive for competitive advantage. Within the latter construct, the authors included as additional factors sustainable actions in the firm's design practice and strategy. Overall, we can see that the proposed framework of this thesis covers the three main constructs of Akadiri and Fadiya's (2013) framework and overlaps with most of the inherited factors of the constructs in their model. The environmental management system, education and training and the financial dimension of the proposed framework are missing in the compared model.

- The third model uses institutional theory in evaluating environmental pressures on the third-party logistics (3PL) sector in China. The study of Chu et al. (2018) examined the moderating effect of market uncertainty on innovation and the performance of organisations. Because of the global economic crisis a decade ago, many organisations around the globe are still operating within turbulent markets, including the construction companies in both countries in this thesis although the situation is more severe in the Greek market. Additional similarities concerning the study of Chu et al. (2018) and the construction industry are the efforts of the organisations to innovate with eco-design building material for reducing energy consumption, as it is discussed throughout this chapter. The conceptual model of Chu et al. (2018) is developed on regulatory pressure, customer pressure and competitive pressure. These act as facilitators for companies to seek green innovations, which in turn influence positively the financial performance of the organisations. Within the financial performance construct, Chu et al. (2018) consider the benefits from an improved corporate image and the green practices in the supply chain. There are some common factors between this model and the proposed framework of the thesis although the author's belief is that the proposed framework covers more areas and is much more suitable to the construction industry's complex supply chains.

In conclusion, two research questions were addressed in this chapter. The participants' perceptions were utilised in the development of a conceptual framework that is compatible with other frameworks/models (RQ2). The uniqueness of the proposed framework lies in the fact that it is constructed on the outcomes of a qualitative approach, giving the opportunity for in-depth discussions of the relevant topics. As demonstrated in the chapter, institutional theory has great relevance in the context of sustainability drivers within the construction industry's supply chains and are addressed in the proposed framework, thus answering the other research question (RQ3). Despite the appropriateness of the methods used in this part of the thesis and the positive outcome in terms of tackling the research questions, the researcher observed some important issues that are not reflected in the conceptual framework but have been addressed during the discussion. First, it is evident that there is lack of a supply chain perspective among professionals in the construction industry, where their main focus is on building material and eco-designs. Second, there seems to be a knowledge deficit of relevant technologies or capabilities of management environmental systems concerning the assessment of carbon footprint. These concerns are related to the assertions of other authors, reporting difficulties in the implementation or understanding of collaboration initiatives for sustainable practices in the supply chain (Renukappa et al., 2012) and unwillingness towards sustainable practices by construction companies in many countries (Chang et al., 2017), although construction firms around the globe are facing almost the same fundamental issues (Balasubramanian and Shukla, 2017). According to Abidin (2010), this disinclination of the industry towards sustainable practices is attributed to cost-related issues (Shi et al., 2013). The environment under which companies operate in the sector is broad, with varied complexity and diversity, and the project-driven reality in construction makes it difficult to engage in sustainability (Balasubramanian and Shukla, 2017). On a similar note, Mukherjee and Muga (cited in Gan et al., 2015) referred to the culture of the construction industry that is driven by profits and focuses on surviving, two elements that hinder sustainability practices.

6 Case Study: Assessing carbon emissions of a Greek SME

6.1 Introduction

This chapter aims to provide the answer to the fourth research question: Does the application of a carbon assessment tool in a Greek SME construction company measure its carbon footprint and allow for interventions to lowering emissions?

In doing so, the author discusses the steps and requirements towards applying the carbon assessment tool by mapping the processes of producing one of the main products of the case-company and performs a carbon assessment of its upstream supply chain. Following that, the author attempts two interventions in the supply chain, in the form of scenarios, in an effort to lower the total carbon emissions caused by the company's processes.

6.2 Outline of the organisation's activities

"**XYZ Company**" was founded in Thessaloniki, Greece as a sole proprietorship, becoming a joint stock company in 1985. It is a construction and infrastructure company with one of its primary business activities being tarmac (asphalt) and concrete manufacture, and is involved in public and private development projects. Its products are used in a range of applications, including blacktop and technical works in both public and private sectors.

The company is regarded as a developing Greek enterprise in the technical products arena and has a dynamic domestic market presence. It produces tarmac in two locations to the west and east of Thessaloniki: Pella and Kassandra, as well as owning mechanical equipment for the execution of works, as well as trucks to transport crude and end products.

The corporate strategy is focused primarily on the following objectives:

- To sustain and enhance the company's progress through innovation and continuous investment.
- To improve both human capital and internal operations.
- To provide clients with an exceptional level of service.

In pursuit of these goals, the company has set up:

- Operating procedures that record and keep track of its activities.
- An efficient system for training staff.

- Good working conditions to ensure that standards mandated by the company's goals for quality are met.
- Acquisition of leading-edge equipment and machinery capable of meeting client demands.
- Procedure control and monitoring using the right tools.

6.3 Producing the tarmac blend

The company is engaged in the manufacture and supply of all kinds of tarmac, but this paper is concerned with the type of tarmac in commonest use, which also comprises the largest part of the company's production.

Tarmac production is a fairly straightforward process and uses raw materials such as sand, gravel and gravel sand that are fairly commonly available. These materials brought on site from the quarry and stored there in silos. A given amount of each is placed into a furnace and the heated blend thus produced is homogenised in an agitator. At the end of this process, tarmac can be delivered as end-product.

In total, the organisation's annual production of blended tarmac is some 169,000 tons at Kassandra and 43,000 tons at Pella. Table 6.1 below shows the annual consumption of utilities for each site.

Table 6-1: Utility consumption per annum

Utilities	Kassandra site	Pella site
Electricity-kWh	95. 978	76.132
Diesel-litres	59.124	14.965
Fuel-oil litres	594.936	30.012

What must also be considered is that besides the burden the two production sites place on the natural environment in the form of greenhouse gases, those interviewed as part of this research affirmed that contaminated water resulting from washing raw materials is the only waste that this industry produces. Before production can start, all dust and other contaminants must be removed so that the raw materials are perfectly clean at the start of the process.

Because of its wish to use recyclable materials throughout its operations, the company also makes use of large quantities of milling tarmac, produced from a blend of recycled blacktop, with a specific percentage of the recycled material being used in production of the new one. The company seeks to integrate the ISO14001into its processes and is taking initial steps to adopt that Environmental Management System.

6.3.1 Mapping the tarmac production with SCEnAT

Within SCEnAT's database, each record is divided into three main fields. The first field is the emission intensity, the second field specifies the sector of the economy in which the material belongs to, while the third field is the unit cost per supply chain input. Information in the first field describes in kg-CO_2eq emission intensity in terms of the process used, the sector, and the location. Eighteen aggregated sectors are contained in the sector classification.

Kassandra is the newer of the two production sites and has better equipment than Pella, though equipment at the older site has been renovated. Five main processes are involved in production of tarmac, each with its own inputs. The two sites differ in terms of inputs and so data were collected separately to make it possible to identify significant deviations in their emissions of CO_2.

In producing tarmac, five major activities are involved. First is transporting the raw materials, then the heating process in a coke oven, followed by mixing the material, raising the temperature of oil in a cogeneration unit, and filtering by way of a disposal filter. A number of inputs are involved in each of these processes and these will be discussed in the following section.

Figures 6.1 and 6.2 show the inputs used in the tarmac supply chain and the processes by which a ton of tarmac blend is produced, mapped in SCEnAT.

The grey colour in graphs 6.1 and 6.2 shows the five processes and the inputs relating to them, while the red polygons are the inputs in the supply chain responsible for the most pollutants – that is, the processes and inputs needing optimisation and requiring intervention by the company for successful reduction of its emissions of greenhouse gases.

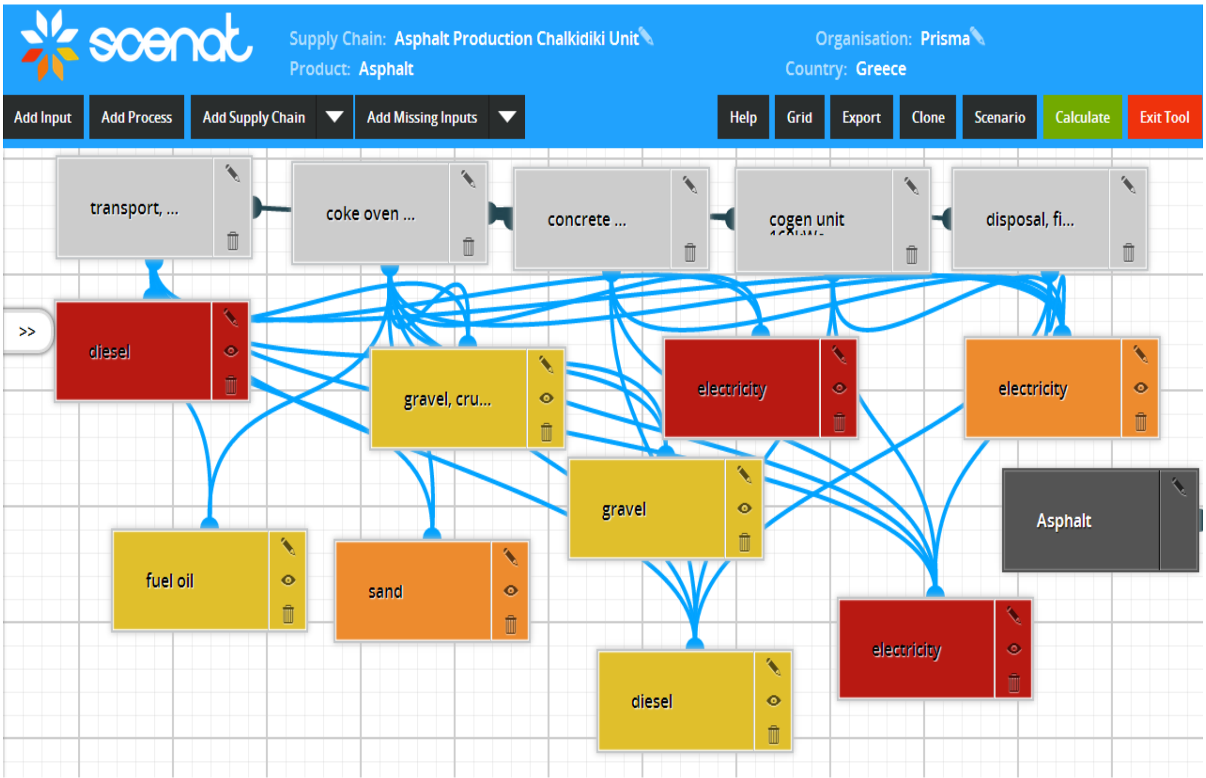


Figure 6.1: Mapping the tarmac production of Kassandra site

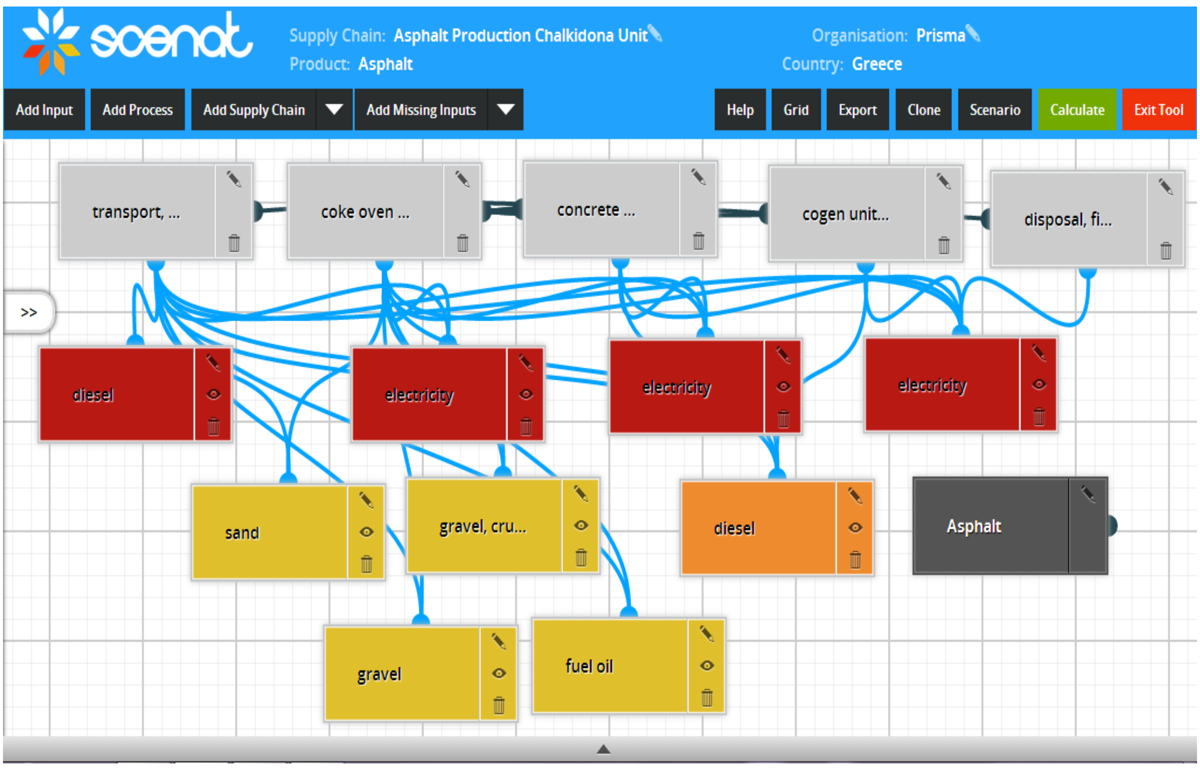


Figure 6.2: Mapping the tarmac production of Pella site

As mentioned above, transport is the first process. The average distance could be calculated only for inbound and not for outbound transport. The main procurers for the company's production sites are coming from the mining industry and the refinery of Thessaloniki; the vehicles used by the company are 16-32 metric ton lorries. Endpoints for distribution vary, preventing the company from reaching an average estimate for outbound transport. Inbound lorries to Kassandra cover on average 52 kilometres as the mine is 34 kilometres away and the refinery 70 kilometres. For Pella, both mine and refinery are at a distance of 30 kilometres.

The analogy between fuel consumption (litres of diesel) and distance travelled (kilometres) is 1:2 for transport.

Heating, in a coke oven at the plant, is the second process and requires the following five inputs: fuel oil and electricity for power, and gravels, sand and crushed-gravel for production of the tarmac-mix. This information was made available to the researcher by referring to various manuals, especially for the coke-oven and the amount of raw-material required producing one ton of tarmac blend.

The third process is to mix the raw materials in a concrete mixing plant, and the only input in this process is electricity for power.

Heating the oil is the fourth process and takes place in a 160kWe cogeneration unit component, which requires only diesel as an input.

The final process is filtering through a dust disposal filter, requiring electricity as the energy source and the only input.

Data provided by SCEnAT for the fuel-related variables concur with European-based measures and the cost per unit is assessed on the basis of annual average costs in Greece for fuel oil and diesel. SCEnAT provides data in Greek measurements and also takes annual average costs in Greece to calculate unit costs.

The only records held by SCEnAT for the raw materials come from the Czech Republic and so unit costs per raw material were calculated on the basis of annual average costs in Greece. Appendices A through H give more detail for all variables used by both tarmac sites covered in this study.

Based on these facts, we conclude that the main sources of energy used by both sites are diesel and electricity. Figures 6.3 and 6.4 show how energy has been allocated for each of the sites.

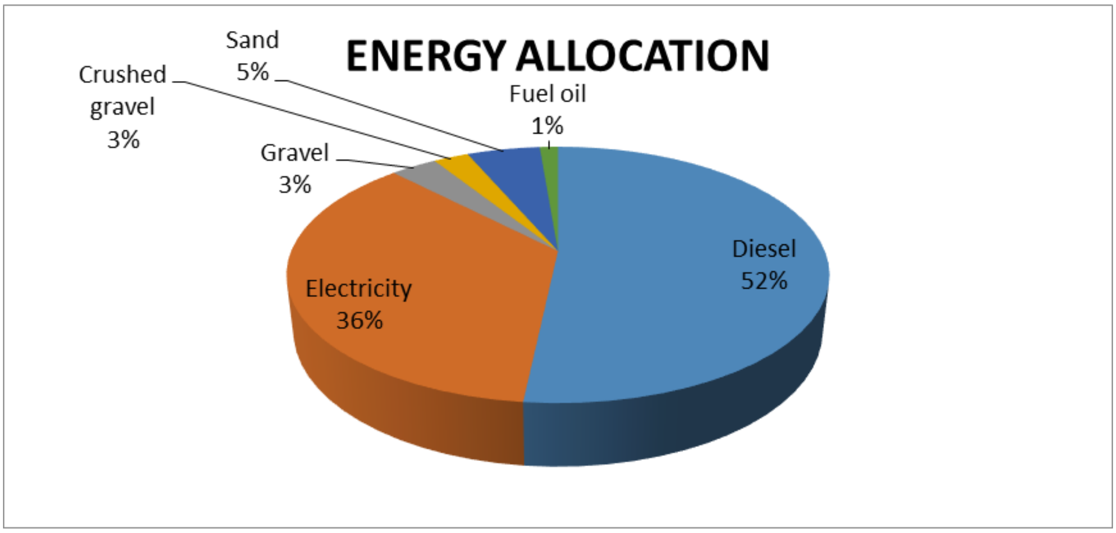


Figure 6.3: Allotment of energy in Kassandra site

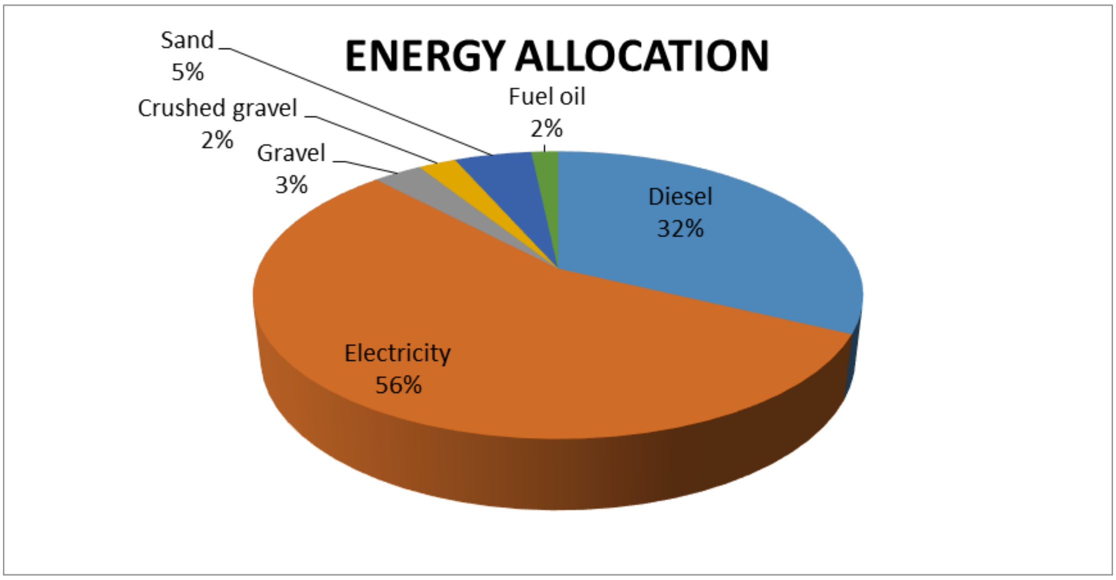


Figure 6.4: Allotment of energy in Pella site

SCEnAT calculates that, in producing one ton of tarmac blend, carbon emissions during the whole lifecycle amount to (in kg-CO_2eq) 25.40 at Kassandra site and 27.25 at Pella. It is also possible to break down total emissions into two categories: impacts of the LCA process and indirect impacts. For both sites, emissions are categorised as LCA impacts and there are no indirect impacts (Appendices E and F for the auto-generated SCEnAT reports).

Given these results, it can be seen that the company emits (kg-CO_2eq) 4,316 for the average 169,900 tons yearly production of tarmac at Kassandra and 1,172 per year to produce an annual average of 43,000 tons at Pella, adding to 5,488 kg-CO_2eq in total.

6.3.1.1 Comparison of sites

In order to service construction sites most efficiently, the two tarmac production units are located in two different regions, Kassandra and Pella. The company's own data indicates that the Kassandra site is at relatively short distance from the mine but not from the refinery. There is only one refinery in Thessaloniki and it locates in the other side of the city, so these two facilities, refinery and production site, are in opposite directions. That is causing greater use of diesel for the Kassandra site than the one at Pella; it breaks down 52% for Kassandra and 32% for Pella.

Pella, on the other hand, uses more electricity (56%) than Kassandra (36%) because it has older equipment. Table 6-2 shows the two sites' electricity usage as presented by the company's own. While electricity consumption appears to diverge only slightly between the two sites, the end-result shows that these differences are enough to affect the production process.

Table 6-2: Use of electricity in both sites

Use of Electricity (Kwh)	Kassandra site	Pella site
Heating	3.96	6.03
Mixing	3.04	5.89

Filtering	2.03	2.91

The data analysis showed which processes emit the highest levels of CO_2 into the environment. This knowledge assists the company in designing and applying strategies to improve its environmental footprint. The section that follows contains recommendations and proposes corrective interventions of two types, which are then analysed.

6.4 Two scenarios

6.4.1 Scenario 1

SCEnAT was used to map the whole SC of tarmac production and identifies consumption of electricity and diesel as the company's main "hotspots" that need to be reduced as part of optimising the company's processes. Substantial reductions are needed in consumption of diesel at Kassandra and of electricity at Pella. It is only possible to bring down consumption of diesel if the distance from suppliers to the site can be reduced and this is not possible because there is only one refinery in Thessaloniki. One way to reduce consumption of electricity at Pella would be either to rehabilitate or to replace old equipment. This strategy was shown to work at Kassandra because using newer equipment allowed the firm to reduce by 19% its consumption of electricity when we compare it with the older site.

It is therefore easy to conclude that CO_2 emissions can be reduced if the company plays to its strengths by building a new unit close to Pella but with the technology used by Kassandra. This is supported by the European Commission (2011b, p. 18) stating, "*Businesses may have to install cleaner technologies or could be restricted in the way that they can produce.*"

SCEnAT has been used to combine process data from the two sites experimentally. The diesel variable describes the amount of diesel used in Pella, while all other variables are taken from Kassandra.

Mapping the scenario, figure 6.5 demonstrates that SCEnAT identified four hotspots, three for electricity and one for diesel usage, even though the diesel variable has been reduced from the 26 litres/ton used in production at Kassandra to the 15 litres/ton obtained at Pella site and figure 6.6 presents the apportionment of total energy.

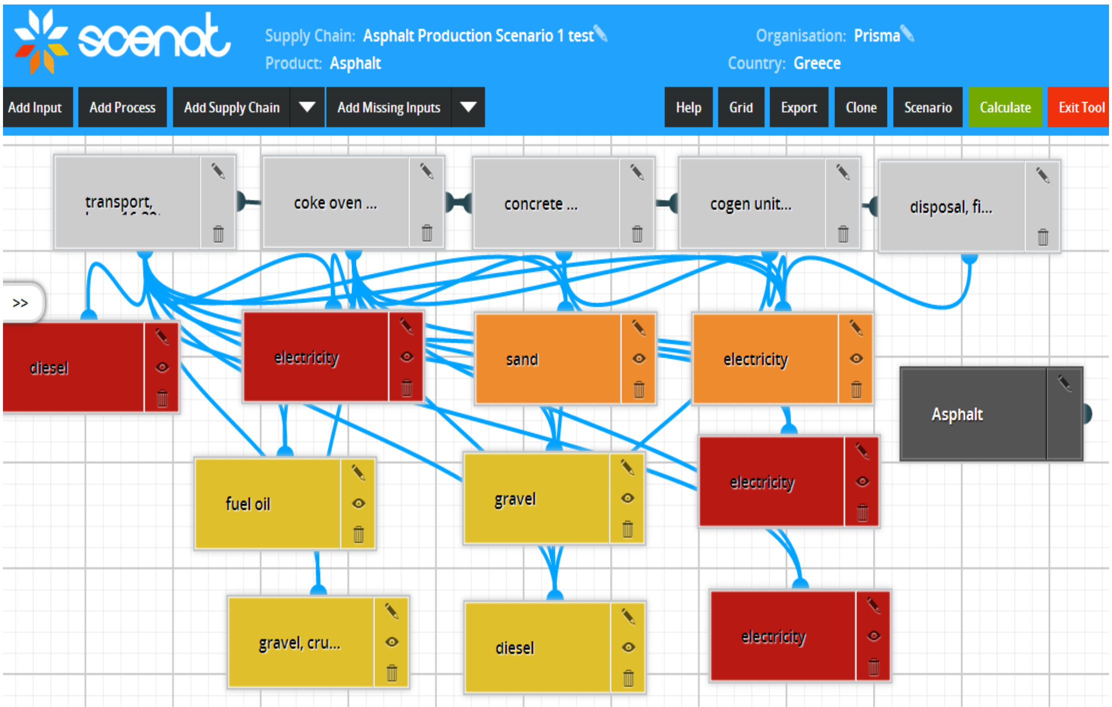


Figure 6.5: Mapping of Scenario 1

SCEnAT's auto-generated report shows that the calculated carbon emissions from a single ton of tarmac blend over the whole life-cycle is 20.01 kg-CO_2eq, which is classified into two types of impacts, those from LCA's process and indirect ones. Once again according to SCEnAT, the emissions the two tarmac production sites generate are only associated with process LCA impacts and not with indirect impacts. (Appendix G for SCEnAT report).

Kassandra's footprint is 25.40 kg-CO_2eq and Pella's 27.25 kg-CO_2eq. Compared with results of the scenario 1, application by the company of this project will decrease its emissions by 21.22%, or 5.39 kg-CO_2eq at Kassandra site and by 26.57%, or 7.23 kg-CO_2eq at Pella site.

In total, according to SCEnAT, the two sites generate an annual 5,488 kg-CO_2eq for production of 212,900 tons. The first intervention's results show total annual emissions of CO_2 at 4,260 kg-CO_2eq, a reduction annually of 1,228 kg-CO_2eq or 22.38% for production of 212,900 tons annually.

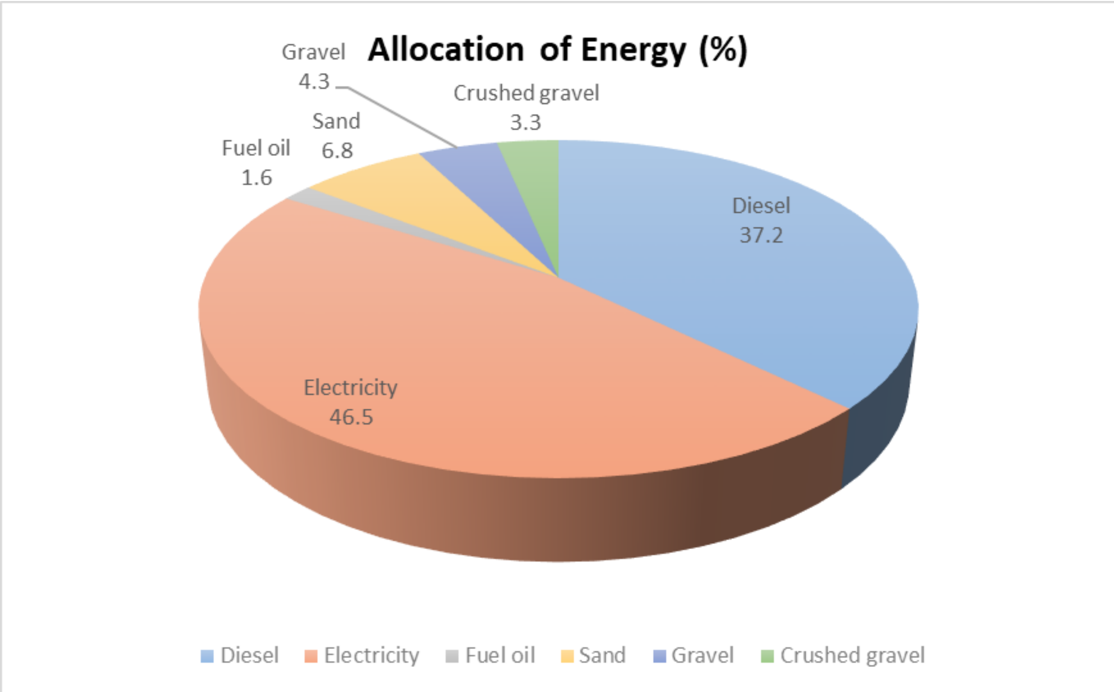


Figure 6.6: Apportionment of energy in scenario 1

There is a disagreement between studies over the importance of transport. In a couple of studies carrying out extensive research into the cement industry, the conclusions were that the results from optimised transport are not worthwhile, amounting to only 2% (Lippiatt and Ahmad, 2004; Masanet et al., 2005). Bilec et al. (2006) disagree, concluding that in construction projects transportation is impacting the environment more than any other factor.

The findings of the present research are in agreement with those of Bilec's et al. (2006) study, because the impact of scenario 1 involved only a decrease of the number of kilometres travelled between suppliers and production sites and led to less diesel being consumed. The total 22.38% reduction did not accord with the 2% suggested by the research of the authors above.

6.4.2 Scenario 2

Scenario 2 suggests that, as it is not possible to further optimise the distance between suppliers and sites, the amount of diesel used during transport by both sites should be the same. What is more, since no interventions are possible in the process of producing tarmac blend, a reduction in fuel oil and electricity used in operating the coke oven and disposal filter and the diesel used by the cogeneration unit could be equal to half of both sites' average consumption while the volumes of raw materials are unchanged (Appendices D for input-data and H for SCEnAT report). Diesel and electricity variables according to SCEnAT are shown in the following diagram.

SCEnAT indicates that annual production of 212,900 tons generates in the same time period 17.03 kg-CO_2eq per ton, which amounts to 3,625 kg-CO_2eq for the annual production. The whole of these emissions result from the process LCA and not from indirect impacts. Most recent results indicate that percentage reduction of CO_2 emissions at Kassandra is 32.96, for the Pella site 37.5, and the total reduction per year for 212,900 tons of tarmac production is 36.05% kg-CO_2eq. In addition, and compared with the scenario 1 results, an annual reduction of 14.9% for the same yearly production of 212,900 tons is available. The total energy allocation is illustrated in figure 6.8.

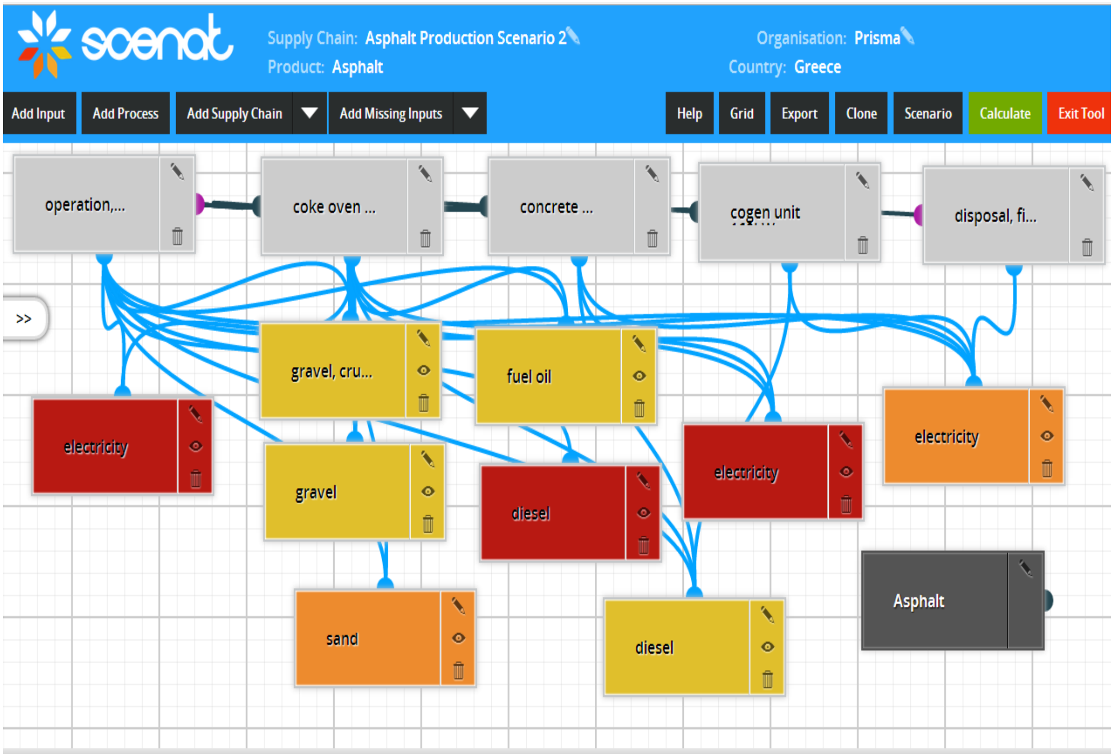


Figure 6.7: Mapping of scenario 2

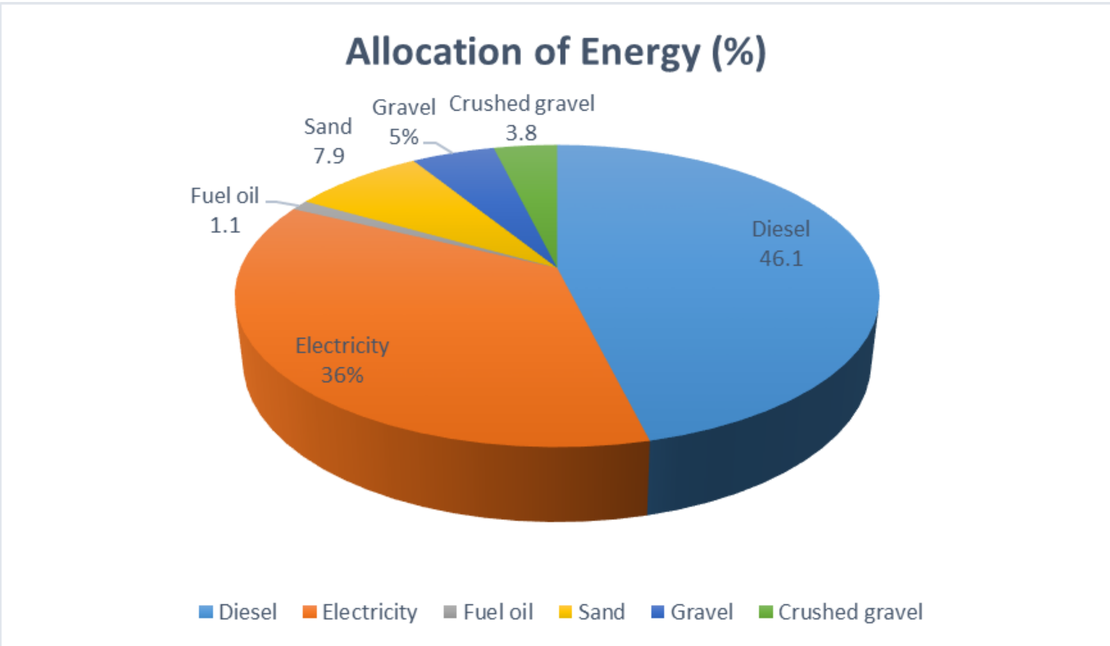


Figure 6.8: Apportionment of energy in scenario 2

7 Conclusions

7.1 Introduction

In this chapter, the author presents a synopsis on how each of the research questions has been approached to fulfilling the aim and objectives of the research. Theoretical and managerial implications of the study are also addressed, followed by its limitations, and concludes with recommendations for further research in the area that would extend the current findings.

7.2 Fulfilling the aim and objectives of the research

The research journey was initiated by the personal concerns of the researcher for the environment and the motivation to support the academic community in its quest to recommend solutions or offer guidance to public and private institutions towards a low-carbon economy. The selection of construction as the focal industry seemed a natural choice since it is the economy sector causing the highest carbon emissions, thus engendering the greatest harm to the planet and the society. The triple bottom line (TBL) framework sets the theoretical frame of the research, together with institutional theory, which explains institutional isomorphism. It is the author's opinion that these isomorphic pressures may be the last resort for organisations to engage actively in sustainable practices.

The aim of this study is to advance the knowledge and know-how of environmental sustainability consciousness and adoption by making theoretical and practical contributions in the construction industry. The research objectives are to

- investigate the extent to which sustainability issues in the UK construction industry have been researched and the areas of focus
- investigate the drivers of sustainable practices among UK and Greek construction companies' supply chains
- examine the suitability of a tool in assessing the carbon footprint of a construction company's supply chain

Four research questions were constructed after a thorough review of the extant literature that identified three gaps, which this thesis aims to fulfil.

RQ1: What is the breadth and depth of the environmental sustainability coverage in the UK construction industry by academia since the inception of the sustainable construction guidelines?

To answer this question, the researcher conducted a systematic literature review, following the PRISMA method, and used the digital library of the University of Liverpool. Twenty bibliographical databases were searched, including Scopus, which is considered to be the most complete database in the social sciences.

The selection process has returned 29 academic articles, which met all the inclusion criteria. The analysis of the extracted resources revealed that the vast majority of the research, more than 70% of the articles, referred to the actual buildings and technological advancements in build material. Eco-designs seem to be the priority in the sector when sustainability is addressed. There is certainly depth in the coverage of such issues and specifically in the operational life of buildings and reductions of the energy they consume. However, in terms of the breadth of research, the existing literature is lacking. A few articles dealt with procurement. It is evident from the extracted resources that generally, there is a lack of supply chain perspective among the focus of the studies and their findings. Only articles or findings referring to procurement have a direct relevance to supply chain management. As suggested by some authors in the returned list of articles, the concept of sustainability is not uniformly understood in the construction industry.

RQ2: What are the perceptions of construction managers, in both UK and Greek construction organisations, in terms of the drivers leading to the adoption of sustainable practices in their organisations and their supply chains, and how are these perceptions constructed?

The second research question aimed to fill another gap in the literature; to the best knowledge of the researcher, no prior study in either the UK or Greece has investigated construction professionals' perceptions on organisational drivers leading to sustainable practices with a purely qualitative approach and using mixed purposive sampling techniques. In addition, the study draws upon the phenomenological constructivist research philosophy to explore the views of the construction managers on sustainability practices within their organisations and their supply chains. Under these terms, the research is unique and makes a theoretical contribution to the field of study.

Twenty-seven managers were interviewed, 13 from UK and 14 from Greece. Data saturation was reached in both groups, and the researcher is confident that the perceptions of these individuals provide a clear picture of the current situation in the industry. The purpose of this part of the research is not to compare the views and beliefs of professionals between the two countries, although minor differences were highlighted during the discussion in Chapter 5. As noted, the fundamental issues inherent to the construction industry are similar in most countries, and it is confirmed by this study for the two countries where the research took place. The findings reveal several interesting insights of the industry. The thematic analysis for the collected data produced nine themes, which are classified as either external and internal drivers.

The emerged external drivers are

- government/EU regulations
- client requirements
- organisational reputation
- external bodies
- competitors

The internal drivers are

- executive management support
- financial dimension
- environmental management systems and software
- education and training

The financial dimension driver was the predominant factor in the perceptions of the participants. This finding confirms the assertions of other authors (Shi et al., 2013; Gan et al., 2015) that construction is a very competitive and intense profit-driven industry, which causes difficulties in initiating sustainable practices. The next driver, closely following the first one in the responses of the participants, is government regulations. This factor is common to all models found in literature. Each of the emergent drivers has been pinpointed in other proposed models, but the combination of the drivers in this thesis is unique.

RQ3: How relevant is institutional theory in the context of sustainability drivers within the construction industry's supply chains?

In this research question, the researcher examined whether the isomorphic pressures of institutional theory could explain the perceptions of the participants. The answer is that institutional pressures are a perfect fit to the construction industry. Interpreting the emerged drivers of the previous section, drawing upon institutional pressures, the researcher developed a conceptual framework to depict the correspondence of the two sets – emergent drivers and institutional pressures – and, through their relationship, show their influence on sustainable practice engagement. The analysis showed government regulations are a coercive pressure; client requirements, organisational reputation, and external bodies are a normative pressure; and competition is mimetic pressure. This fully explained the external drivers of the conceptual framework. Institutional pressures also exert pressure on the internal factors, as discussed in Chapter 5, but there were no clear indications how they are exerted, as this can change from company to company depending on the environment in which they operate. Quantitative research could shed light on this issue, identifying causal links. A comparison of the proposed framework with three other models of the literature showed at least the compatibility of our module with the rest.

RQ4: Does the application of a carbon assessment tool in a Greek SME construction company measure its carbon footprint and allow for interventions to lowering emissions?

The last research question involved a case study of a Greek SME. It produces tarmac (asphalt) and concrete (cement) in two locations to the west and east of Thessaloniki – Pella and Kassandra – as well as owns mechanical equipment for the execution of works and trucks to transport crude and end products. The researcher utilised the SCEnAT to measure the carbon footprint of tarmac production. Results have shown that this is not only possible, but the software also identifies the 'hotspots' of the process. Hotspots are those activities with the highest emissions of carbon-equivalent gases. This gives the opportunity to act on those activities to modify them if possible, thus lowering the total carbon footprint of the company. The researcher has experimented with two different scenarios by intervening in the said processes, realising reductions in the total emissions of the processes involved. This confirms the significance of the 'environmental management system and software' driver and the proposed conceptual framework as a whole.

An interesting remark is that interventions in the downstream supply chain of a construction company are difficult to be made because of the nature of the industry. Transportation costs and/or emissions caused by downstream activities can be realised almost exclusively by the use of low-energy consumption trucks. For example, consolidated shipments used strategically in other industries are very rare in construction because of the nature of the products (concrete or tarmac). Only supplier deliveries to the building sites of other needed construction materials can take advantage of consolidations such as bricks. Research by Masanet et al. (2005) into the construction industry suggests that improving transport improves results by only 2%. On the contrary, a case study using hybrid LCA methodology revealed that transportation and reallocation of equipment cause the highest emissions in the industry (Bilec et al., 2006). The distance between the suppliers and the construction site for moving the construction materials were considered when calculating the carbon footprint. In that case, a crucial issue is who incurs these costs. A solution to this problem, if possible, would be near sourcing. All these explain, at least partially, the passive culture (Abidin, 2010) of the construction industry towards supply chain collaboration.

7.3 Theoretical and managerial contributions

7.3.1 Theoretical contributions

A major strength of this thesis is its engagement with three different methodological approaches: systematic literature review, qualitative research and a case study. The first two of these approaches make theoretical contributions to the construction industry's green supply chains research area.

1. Systematic literature review. A systematic review of sustainable practices in the UK construction industry is missing from the existing literature. There are three studies which fail to provide coverage of a holistic view of the topic. Myers (2005) examined the sustainability involvement of construction companies listed in the London Stock Exchange, but his research was based on public disclosures of those organisations. The other two more recent studies encompassing systematic reviews by Darko et al. (2017) and Darko and Chan (2016) were narrowed down to green buildings and have a global focus, including the UK. Thus, the systematic review in this thesis is unique and serves as a guide to future researchers of the topic.

2. Qualitative research. Various articles have drawn on institutional theory to investigate the drivers of adopting sustainable practices, including the construction industry. Mixed methods or quantitative approaches were employed in the reported cases. To the knowledge of the researcher, the current study is the first to use in-depth interviews and institutional pressures to arrive at a conceptual framework. Therefore, both the approach and the conceptual framework are contributions of this study to the field and future researchers. Furthermore, the study is the first to use the above elements in the UK and Greek construction industry.

3. The current study is the only one in the field that combines homogenous purposive sampling with exponential discriminative snowball sampling, otherwise referred to as mixed purposive sampling (Patton, 2002; Patton, 2015).

4. An additional contribution to the research area is the epistemological stance taken by the researcher to provide a deep knowledge of the phenomenon. The study embodies the

phenomenological constructivist research philosophy, which draws information from sources of intuitive, authoritarian, logical and empirical knowledge (Dudovskiy, n.d.). No other study has been found to accommodate this philosophical stance in the field.

7.3.2 Managerial contributions

There are two main managerial contributions of this study:

1. Conceptual framework. This framework can be used as a guide by construction organisations attempting to engage in sustainable practices. Emphasis should be given to the internal drivers where the executive management support driver is of significant importance to initiating and supporting such actions. The financial dimension driver should not be an obstacle if the organisation can afford the upfront costs. It must be seen as an investment that will yield various benefits including lower operating costs (Taylor and Wilkie, 2008), improved organisational image and reputation (Singh and Gupta, 2014; Asif et al., 2013) and greater satisfaction of stakeholders (Higham & Thomson, 2015; Hopkins, 2016), either internal or external, such as customers and employees. Educating and training employees is of utmost importance, as human capital is key to an organisation's strategy and is therefore worth investing in. Organisations should increase employees' sustainability consciousness by educating them through internal seminars. This study identified the lack of a supply chain perspective among the interview participants. Managers in key roles within an organisation should increase their environmental awareness and knowledge (Abidin, 2010) and that of their employees. In recent studies, only procurement employees seem to have received such training (Brooks & Rich 2016), but project managers must be trained as well.

2. Environmental management systems and carbon footprint. Regarding education and training, the application of SCEnAT in assessing the carbon footprint of a construction company demonstrated that it is possible to make interventions in the processes of a company and its supply chain and further lower carbon emissions. Organisations have to raise their awareness of the existence of such tools in the market or those made available by the government in the case of the UK, and use them for the benefit of their organisations and of society. Employees must be trained in the effective use of such systems. Lowering carbon emissions translates into cost savings.

7.4 Limitations of the study

There are certain limitations of the study:

- Although information-rich cases (i.e., participants' roles in their organisations) are highly sought in qualitative research to gain an in-depth understanding of a phenomenon, a quantitative approach would have provided evidence of the strength of relations among the emergent drivers and possibly the breadth of the study.
- Data saturation was reached in both groups of participants, but unfortunately, generalisation of the results cannot be assumed because of the nature of the research.
- Lack of relevant literature on the Greek construction industry has reduced the impact of the systematic review, as it would have been much stronger if both countries were included.
- The application of SCEnAt in only one construction company poses a risk to disseminate its effectiveness although the tool has been tested in other industries as well.
- SCEnAT used data from the production process of one product and data from the company's upstream supply chain. No availability of downstream data was possible because of ethical reasons raised by the case company.

7.5 Recommendations for further research

The author sees two possible research opportunities, stemming from the current study, which would make significant theoretical and practical contributions.

- First, a quantitative study, especially in the Greek construction industry, but also in other countries, to identify the drivers of sustainable practices within organisations and across their supply chains. The challenges, risks and opportunities to firms regarding climate change can be addressed using a survey as the main research instrument, giving greater breadth in the research. Such study has not yet been conducted and would greatly contribute to the field.
- The second recommendation concerns research on the feasibility and implementation of a carbon emissions reporting platform. The government or professional associations should collaborate with organisations that are not obligated by law to report their carbon footprint but need to comply with certain regulations, to allow them to do so on a voluntary basis and support them in finding ways to reduce it. This process entails a central platform hosting a software tool such as SCEnAT and a national or industry-

specific database. Firms will be sending data to the system, and the government/professional association authority will evaluate their carbon footprint. Results of the assessments will be sent back to the firms, highlighting the 'hotspots' of their processes and providing guidance on potential interventions to lower these emissions. Following this information-flow process, firms will can concentrate on specific activities needing further attention. A major advantage of using SCEnAT for assessing carbon emissions is that it is a cloud-computing platform, thus reaping the benefits of cloud technology. An indicative draft framework in the form of a flow chart is shown in Figure 7.1.

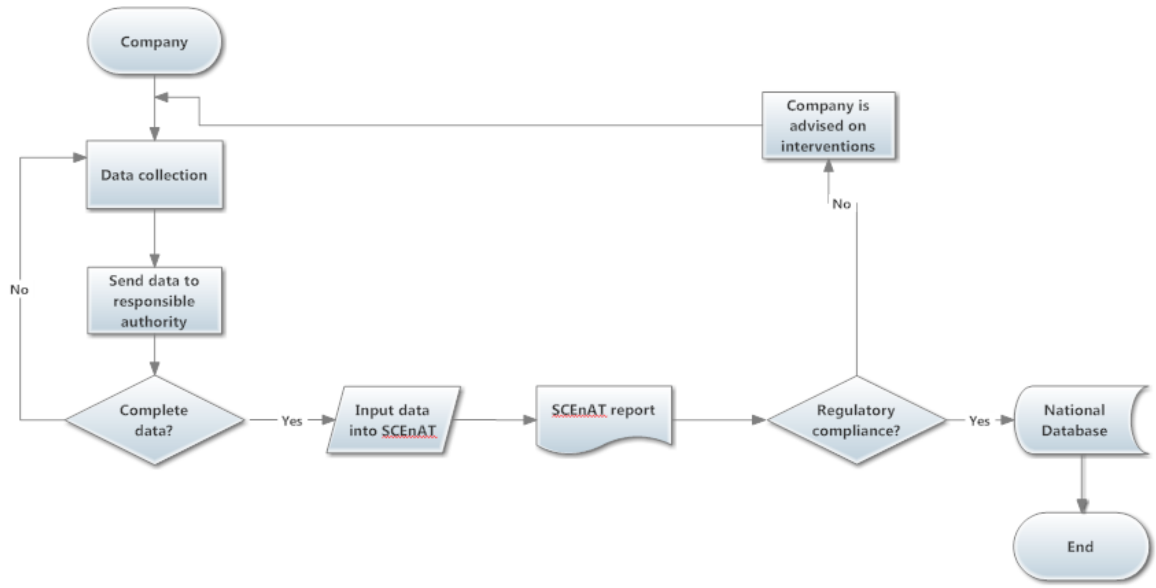


Figure 7.1: An indicative draft framework for assessing environmental regulatory compliance

The draft framework provides a uniform approach to assessing regulatory compliance and could be implemented in a manner that enables participant organisations, and consequently society, to benefit from the recommended interventions. By using SCEnAT, a national database can be developed that can serve as a knowledge base system in this area. The implementation of such platform will assist Greek organisations in any industry to engage more actively in sustainable practices and publish their results to strengthen their reputation and position against competition. After all, Greece is last among southern European countries in the dissemination of corporate social responsibility reports (Tarquinio, 2018).

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9 Appendix A: SCEnAT input data for Kassandra site

Table 9-1: Production-process data (Kassandra site)

Coke oven gas, at plant (Global measurement)	
Name	Electricity
Sector	Utilities
Classification	Electricity: Production, collection and distribution
Quantity	4
Unit	KWh
Emission Intensity (Kg CO_2-eq/unit)	1.0147 (electricity, high voltage, production GR, at grid)
Unit Cost	0.082£
Name	Fuel Oil
Sector	Fuels
Classification	Petroleum & Coke
Quantity	3.5
Unit	Liter
Emission Intensity (Kg CO_2-eq/unit)	0.091023
Unit Cost	0.0293£
Name	Sand
Sector	Mining
Classification	Other mining
Quantity	550
Unit	Kg
Emission Intensity (Kg CO_2-eq/unit)	0.0024214 (Sand at mine, Czech Republic)
Unit Cost	0.875£ (Greek average)
Name	Gravel
Sector	Mining
Classification	Other mining
Quantity	300
Unit	Kg
Emission Intensity (Kg CO_2-eq/unit)	0.0028118 (Gravel, unspecified, at mine, Czech Republic)
Unit Cost	0.1625£ (Greek average)
Name	Gravel, crushed, at mine
Sector	Mining
Classification	Other mining
Quantity	150
Unit	Kg
Emission Intensity (Kg CO_2-eq/unit)	0.0042805 (Gravel, crushed, at mine, Czech Republic)
Unit Cost	0.1578£ (Greek average)

Table 9-2: Transportation data (Kassandra site)

Transport lorry 16-32t, EURO3 (Europe measurement)	
Name	Diesel
Sector	Fuels
Classification	Petroleum & Coke: coke oven products
Quantity	26
Unit	Liter
Emission Intensity (Kg CO_2-eq/unit)	0.48616 (diesel in refinery, Europe)
Unit Cost	1.063£ (Greek average)

Table 9-3: Mixing-plant data (Kassandra site)

Concrete mixing plant	
Name	Electricity
Sector	Utilities
Classification	Electricity: Production, collection and distribution
Quantity	3
Unit	KWh
Emission Intensity (Kg CO_2-eq/unit)	1.0147 (electricity, high voltage, production GR, at grid)
Unit Cost	0.082£

Table 9-4: Co-generator-unit data (Kassandra site)

Co-generator unit 160 KWe components for heat only	
Name	Diesel
Sector	Fuels
Classification	Petroleum & Coke: coke oven products
Quantity	1
Unit	Liter
Emission Intensity (Kg CO_2-eq/unit)	0.48616 (diesel in refinery, Europe)
Unit Cost	1.063£ (Greek average)

Table 9-5: Filter-dust data (Kassandra site)

Disposal filter dust	
Name	Electricity
Sector	Utilities
Classification	Electricity: Production, collection and distribution
Quantity	2
Unit	KWh
Emission Intensity (Kg CO_2-eq/unit)	1.0147 (electricity, high voltage, production GR, at grid)
Unit Cost	0.082£

10 Appendix B: SCEnAT input data for Pella site

Table 10-1: Production-process data (Pella site)

Coke oven gas, at plant (Global measurement)	
Name	Electricity
Sector	Utilities
Classification	Electricity: Production, collection and distribution
Quantity	6
Unit	KWh
Emission Intensity (Kg CO_2-eq/unit)	1.0147 (electricity, high voltage, production GR, at grid)
Unit Cost	0.082£
Name	Fuel Oil
Sector	Fuels
Classification	Petroleum & Coke
Quantity	5
Unit	Liter
Emission Intensity (Kg CO_2-eq/unit)	0.091023
Unit Cost	0.0293£
Name	Sand
Sector	Mining
Classification	Other mining
Quantity	550
Unit	Kg
Emission Intensity (Kg CO_2-eq/unit)	0.0024214 (Sand at mine, Czech Republic)
Unit Cost	0.875£ (Greek average)
Name	Gravel
Sector	Mining
Classification	Other mining
Quantity	300
Unit	Kg
Emission Intensity (Kg CO_2-eq/unit)	0.0028118 (Gravel, unspecified, at mine, Czech Republic)
Unit Cost	0.1625£ (Greek average)
Name	Gravel, crushed, at mine
Sector	Mining
Classification	Other mining
Quantity	150
Unit	Kg
Emission Intensity (Kg CO_2-eq/unit)	0.0042805 (Gravel, crushed, at mine, Czech Republic)
Unit Cost	0.1578£ (Greek average)

Table 10-2: Transportation data (Pella site)

Transport lorry 16-32t, EURO3 (Europe measurement)	
Name	Diesel
Sector	Fuels
Classification	Petroleum & Coke: coke oven products
Quantity	15
Unit	Liter
Emission Intensity (Kg CO_2-eq/unit)	0.48616 (diesel in refinery, Europe)
Unit Cost	1.063£ (Greek average)

Table 10-3: Mixing-plant data (Pella site)

Concrete mixing plant	
Name	Electricity
Sector	Utilities
Classification	Electricity: Production, collection and distribution
Quantity	6
Unit	KWh
Emission Intensity (Kg CO_2-eq/unit)	1.0147 (electricity, high voltage, production GR, at grid)
Unit Cost	0.082£

Table 10-4: Co-generator-unit data (Pella site)

Co-generator unit 160 KWe components for heat only	
Name	Diesel
Sector	Fuels
Classification	Petroleum & Coke: coke oven products
Quantity	3
Unit	Liter
Emission Intensity (Kg CO_2-eq/unit)	0.48616 (diesel in refinery, Europe)
Unit Cost	1.063£ (Greek average)

Table 10-5: Filter-dust data (Pella site)

Disposal filter dust	
Name	Electricity
Sector	Utilities
Classification	Electricity: Production, collection and distribution
Quantity	3
Unit	KWh
Emission Intensity (Kg CO_2-eq/unit)	1.0147 (electricity, high voltage, production GR, at grid)
Unit Cost	0.082£

11 Appendix C: SCEnAT input data for scenario 1

Table 11-1: Production-process data (Scenario 1)

Coke oven gas, at plant (Global measurement)	
Name	Electricity
Sector	Utilities
Classification	Electricity: Production, collection and distribution
Quantity	4
Unit	KWh
Emission Intensity (Kg CO_2-eq/unit)	1.0147 (electricity, high voltage, production GR, at grid)
Unit Cost	0.082£
Name	Fuel Oil
Sector	Fuels
Classification	Petroleum & Coke
Quantity	3,5
Unit	Liter
Emission Intensity (Kg CO_2-eq/unit)	0.091023
Unit Cost	0.0293£
Name	Sand
Sector	Mining
Classification	Other mining
Quantity	550
Unit	Kg
Emission Intensity (Kg CO_2-eq/unit)	0.0024214 (Sand at mine, Czech Republic)
Unit Cost	0.875£ (Greek average)
Name	Gravel
Sector	Mining
Classification	Other mining
Quantity	300
Unit	Kg
Emission Intensity (Kg CO_2-eq/unit)	0.0028118 (Gravel, unspecified, at mine, Czech Republic)
Unit Cost	0.1625£ (Greek average)
Name	Gravel, crushed, at mine
Sector	Mining
Classification	Other mining
Quantity	150
Unit	Kg
Emission Intensity (Kg CO_2-eq/unit)	0.0042805 (Gravel, crushed, at mine, Czech Republic)
Unit Cost	0.1578£ (Greek average)

Table 11-2: Transportation data (Scenario 1)

Transport lorry 16-32t, EURO3 (Europe measurement)	
Name	Diesel
Sector	Fuels
Classification	Petroleum & Coke: coke oven products
Quantity	15
Unit	Liter
Emission Intensity (Kg CO_2-eq/unit)	0.48616 (diesel in refinery, Europe)
Unit Cost	1.063£ (Greek average)

Table 11-3: Mixing-plant data (Scenario 1)

Concrete mixing plant	
Name	Electricity
Sector	Utilities
Classification	Electricity: Production, collection and distribution
Quantity	3
Unit	KWh
Emission Intensity (Kg CO_2-eq/unit)	1.0147 (electricity, high voltage, production GR, at grid)
Unit Cost	0.082£

Table 11-4: Co-generator-unit data (Scenario 1)

Co-generator unit 160 KWe components for heat only	
Name	Diesel
Sector	Fuels
Classification	Petroleum & Coke: coke oven products
Quantity	1
Unit	Liter
Emission Intensity (Kg CO_2-eq/unit)	0.48616 (diesel in refinery, Europe)
Unit Cost	1.063£ (Greek average)

Table 11-5: Filter-dust data (Scenario 1)

Disposal filter dust	
Name	Electricity
Sector	Utilities
Classification	Electricity: Production, collection and distribution
Quantity	2
Unit	KWh
Emission Intensity (Kg CO_2-eq/unit)	1.0147 (electricity, high voltage, production GR, at grid)
Unit Cost	0.082£

12 Appendix D: SCEnAT input data for scenario 2

Table 12-1: Production-process data (Scenario 2)

Coke oven gas, at plant (Global measurement)	
Name	Electricity
Sector	Utilities
Classification	Electricity: Production, collection and distribution
Quantity	2.5
Unit	KWh
Emission Intensity (Kg CO_2-eq/unit)	1.0147 (electricity, high voltage, production GR, at grid)
Unit Cost	0.082£
Name	Fuel Oil
Sector	Fuels
Classification	Petroleum & Coke
Quantity	2.125
Unit	Liter
Emission Intensity (Kg CO_2-eq/unit)	0.091023
Unit Cost	0.0293£
Name	Sand
Sector	Mining
Classification	Other mining
Quantity	550
Unit	Kg
Emission Intensity (Kg CO_2-eq/unit)	0.0024214 (Sand at mine, Czech Republic)
Unit Cost	0.875£ (Greek average)
Name	Gravel
Sector	Mining
Classification	Other mining
Quantity	300
Unit	Kg
Emission Intensity (Kg CO_2-eq/unit)	0.0028118 (Gravel, unspecified, at mine, Czech Republic)
Unit Cost	0.1625£ (Greek average)
Name	Gravel, crushed, at mine
Sector	Mining
Classification	Other mining
Quantity	150
Unit	Kg
Emission Intensity (Kg CO_2-eq/unit)	0.0042805 (Gravel, crushed, at mine, Czech Republic)
Unit Cost	0.1578£ (Greek average)

Table 12-2: Transportation data (Scenario 2)

Name	Diesel
Sector	Fuels
Classification	Petroleum & Coke: coke oven products
Quantity	15
Unit	Liter
Emission Intensity (Kg CO_2-eq/unit)	0.48616 (diesel in refinery, Europe)
Unit Cost	1.063£ (Greek average)

Table 12-3: Mixing-plant data (Scenario 2)

Concrete mixing plant	
Name	Electricity
Sector	Utilities
Classification	Electricity: Production, collection and distribution
Quantity	2.25
Unit	KWh
Emission Intensity (Kg CO_2-eq/unit)	1.0147 (electricity, high voltage, production GR, at grid)
Unit Cost	0.082£

Table 12-4: Co-generator-unit data (Scenario 2)

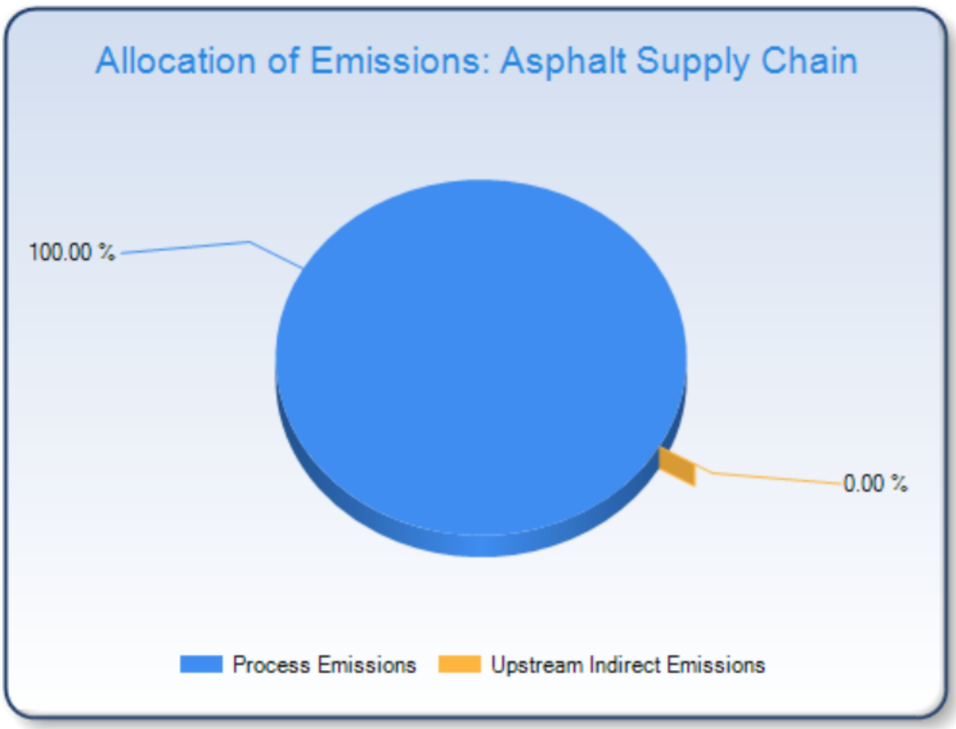
Co-generator unit 160 KWe components for heat only	
Name	Diesel
Sector	Fuels
Classification	Petroleum & Coke: coke oven products
Quantity	1
Unit	Liter
Emission Intensity (Kg CO_2-eq/unit)	0.48616 (diesel in refinery, Europe)
Unit Cost	1.063£ (Greek average)

Table 12-5: Filter-dust data (Scenario 2)

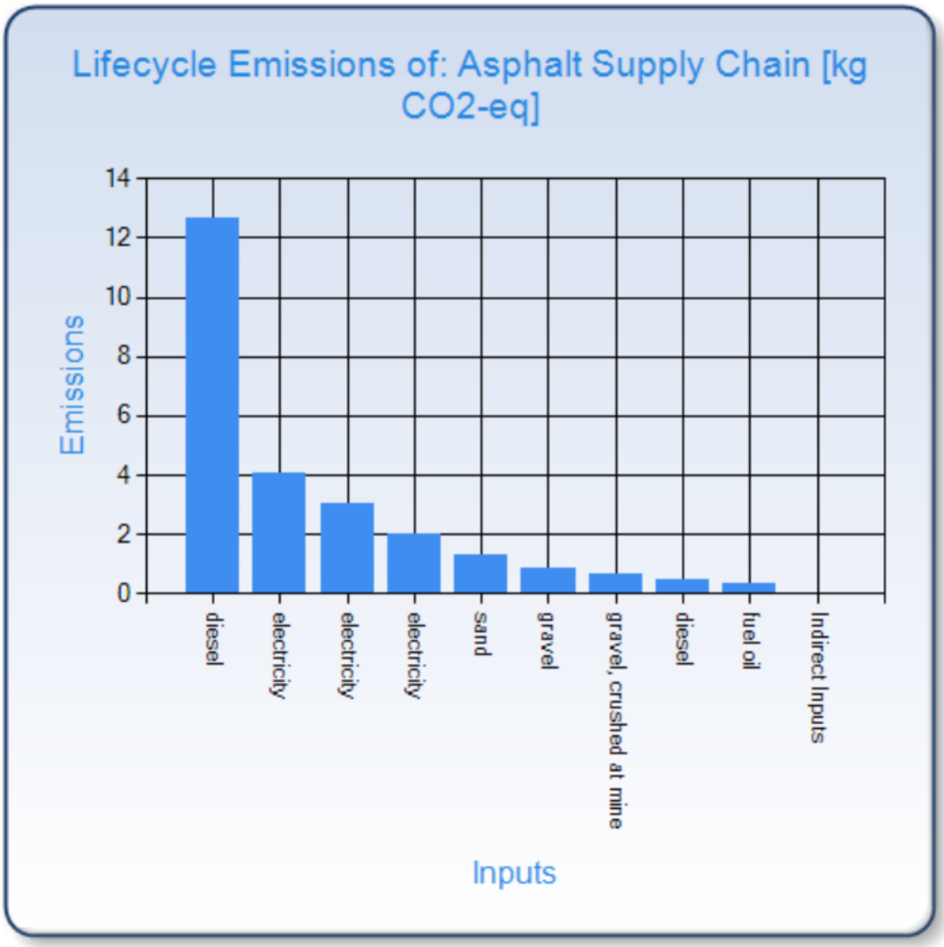
Disposal filter dust	
Name	Electricity
Sector	Utilities
Classification	Electricity: Production, collection and distribution
Quantity	1.25
Unit	KWh
Emission Intensity (Kg CO_2-eq/unit)	1.0147 (electricity, high voltage, production GR, at grid)
Unit Cost	0.082£

13 Appendix E: Auto-generated report for Kassandra site

The Supply Chain Environmental Analysis Tool (SCEnAT) was used to model the Tarmac Supply Chain of Tarmac XYZ (Kassandra site) in order to evaluate the total lifecycle carbon emissions, identify carbon-hotspots and suggest possible low carbon intervention measures to address the hot spots. The results of lifecycle assessment (LCA) undertaken using the Hybrid LCA methodology are based on the environmental impacts due to global warming potential of the Tarmac Supply Chain. The total lifecycle carbon emissions were estimated to be 25.40 kg CO_2-eq/ton. This can further be divided into two main categories: process LCA impacts and indirect impacts. The process LCA impacts contributed 100.00 % of the total lifecycle impacts of the Tarmac Supply Chain. Indirect impacts associated with the supply chain were estimated to be 0.00 %. These indirect impacts arise from emissions associated with indirect inputs from the industries aggregated across 18 sectors namely: Agriculture, Forestry, Mining, Food, Construction, Trade, Transport & Communication, Business services, Personal Services, Textiles, Wood & Paper, Fuels, Chemicals, Minerals, Metals, Equipment, Utilities, Construction, Trade, Transport & Communication, Business services, Personal Services.



The use of the robust Hybrid LCA ensures that those inputs that might otherwise be missed in the process LCA system, such as construction of commercial buildings (to account for construction of plants and related buildings), service related inputs (such as administration and business related activities), and other special purpose machineries for instance are captured. The Lifecycle Emissions of the Tarmac Supply Chain are presented below in a bar chart. It consists of all direct and indirect inputs into the LCA system, classified into different input categories.



The results of the carbon accounting module of the Tarmac Supply Chain estimated using the Hybrid methodology are translated into a supply chain carbon map to identify carbon hotspots and quantify their impacts. The following scale is used in the ranking: Very High (input box colour coded in red, indicates inputs with emissions greater than 10% of the total lifecycle emissions); High (orange; 5-10%); Medium (yellow; 1-5%); Low (green; below 1%).

Full Supply Chain Data

Input Name	Amount	Avg. Unit Cost	Emission Intensity	Carbon Emissions	Emission %
diesel	26.00litre	$1.06	0.4862	12.6402	49.8%
electricity	4.00kWh	$0.08	1.0147	4.0588	16.0%
electricity	3.00kWh	$0.08	1.0147	3.0441	12.0%
electricity	2.00kWh	$0.08	1.0147	2.0294	8.0%
sand	550.00kg	$0.73	0.0024	1.3318	5.2%
gravel	300.00kg	$0.16	0.0028	0.8435	3.3%
gravel, crushed at mine	150.00kg	$0.16	0.0043	0.6421	2.5%
diesel	1.00litre	$1.06	0.4862	0.4862	1.9%
fuel oil	3.50litre	$0.03	0.0910	0.3186	1.3%

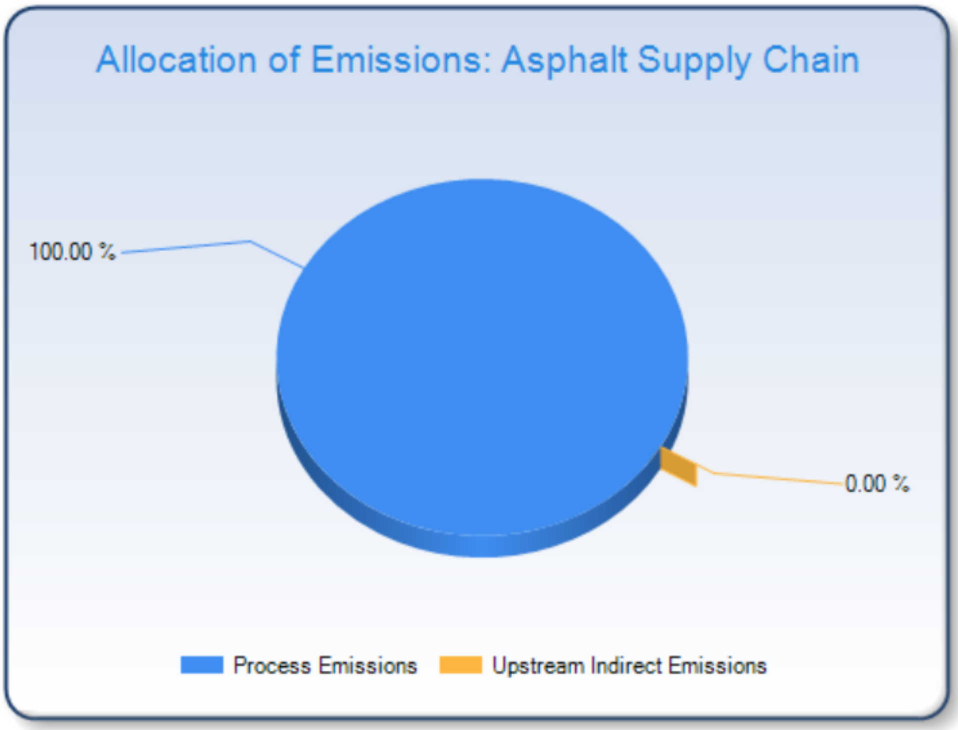
The concept of a supply chain carbon map within a complete system boundary provides insight to users and assists in the design of low carbon products and supply chains. This approach improves the effectiveness of carbon reductions in the overall supply chain by directing investment either to reduce emissions from internal processes or by helping supply chain partners and suppliers to reduce their own carbon intensity. The generated supply chain carbon maps within SCEnAT serves to provide evidence in order to adopt relevant low carbon intervention strategies in reducing carbon emissions in the Tarmac Supply Chain by targeting identified carbon hot-spots after the carbon calculation. A sample of possible interventions to target the identified carbon hot-spots is reported in the following table.

Top 3 Carbon Intensive Direct Inputs

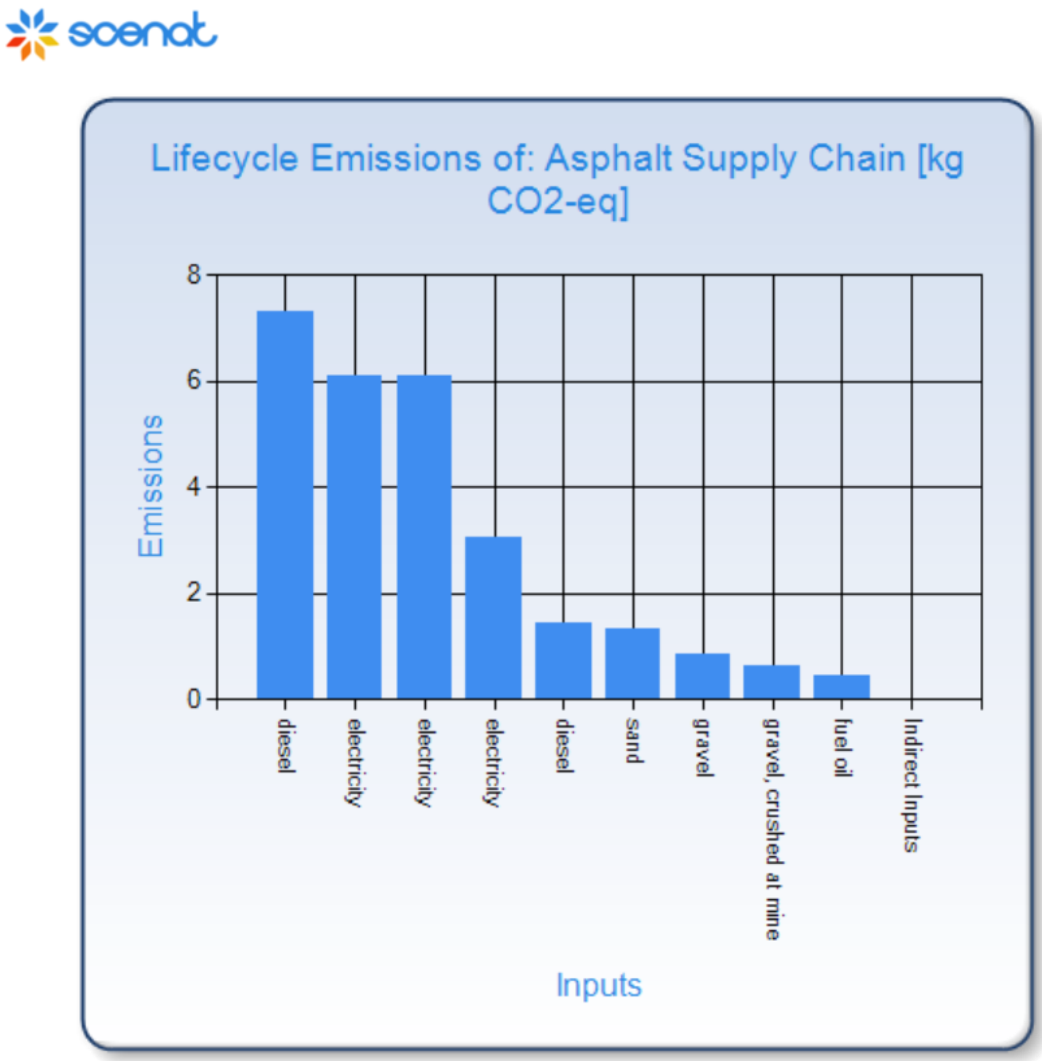
Input Name	Carbon Emissions	Emission %
diesel	12.6402	49.8%
electricity	4.0588	16.0%
electricity	3.0441	12.0%

14 Appendix F: Auto-generated report for Pella site

The Supply Chain Environmental Analysis Tool (SCEnAT) was used to model the Tarmac Supply Chain of Tarmac XYZ (Pella site) in order to evaluate the total lifecycle carbon emissions, identify carbon-hotspots and suggest possible low carbon intervention measures to address the hotspots. The results of lifecycle assessment (LCA) undertaken using the Hybrid LCA methodology are based on the environmental impacts due to global warming potential of the Tarmac Supply Chain. The total lifecycle carbon emissions were estimated to be 27.25 kg CO_2-eq/ton. This can further be divided into two main categories: process LCA impacts and indirect impacts. The process LCA impacts contributed 100.00 % of the total lifecycle impacts of the Tarmac Supply Chain. Indirect impacts associated with the supply chain were estimated to be 0.00 %. These indirect impacts arise from emissions associated with indirect inputs from the industries aggregated across 18 sectors namely: Agriculture, Forestry, Mining, Food, Textiles, Wood & Paper, Fuels, Chemicals, Minerals, Metals, Equipment, Utilities, Construction, Trade, Transport & Communication, Business services, Personal Services.



The use of the robust Hybrid LCA ensures that those inputs that might otherwise be missed in the process LCA system, such as construction of commercial buildings (to account for construction of plants and related buildings), service related inputs (such as administration and business related activities), and other special purpose machineries for instance are captured. The Lifecycle Emissions of the Tarmac Supply Chain are presented below in a bar chart. It consists of all direct and indirect inputs into the LCA system, classified into different input categories.



The results of the carbon accounting module of the Tarmac Supply Chain estimated using the Hybrid methodology are translated into a supply chain carbon map to identify carbon hotspots and quantify their impacts. The following scale is used in the ranking: Very High (input box colour coded in red, indicates inputs with emissions greater than 10% of the total lifecycle emissions); High (orange; 5-10%); Medium (yellow; 1-5%); Low (green; below 1%).

Full Supply Chain Data

Input Name	Amount	Avg. Unit Cost	Emission Intensity	Carbon Emissions	Emission %
diesel	15.00litre	$1.06	0.4862	7.2924	26.8%
electricity	6.00kWh	$0.08	1.0147	6.0882	22.3%
electricity	6.00kWh	$0.08	1.0147	6.0882	22.3%
electricity	3.00kWh	$0.08	1.0147	3.0441	11.2%
diesel	3.00litre	$1.06	0.4862	1.4585	5.4%
sand	550.00kg	$0.73	0.0024	1.3318	4.9%
gravel	300.00kg	$0.16	0.0028	0.8435	3.1%
gravel, crushed at mine	150.00kg	$0.16	0.0043	0.6421	2.4%
fuel oil	5.00litre	$0.03	0.0910	0.4551	1.7%

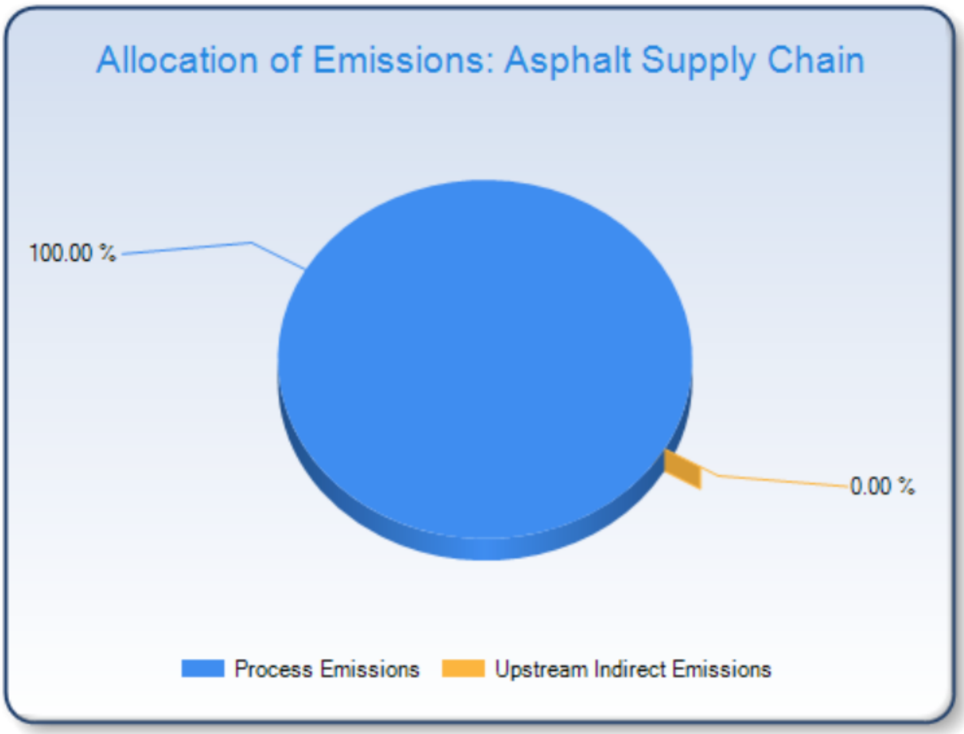
The concept of a supply chain carbon map within a complete system boundary provides insight to users and assists in the design of low carbon products and supply chains. This approach improves the effectiveness of carbon reductions in the overall supply chain by directing investment either to reduce emissions from internal processes or by helping supply chain partners and suppliers to reduce their own carbon intensity. The generated supply chain carbon maps within SCEnAT serves to provide evidence in order to adopt relevant low carbon intervention strategies in reducing carbon emissions in the Tarmac Supply Chain by targeting identified carbon hot-spots after the carbon calculation. A sample of possible interventions to target the identified carbon hot-spots is reported in the following table.

Top 3 Carbon Intensive Direct Inputs

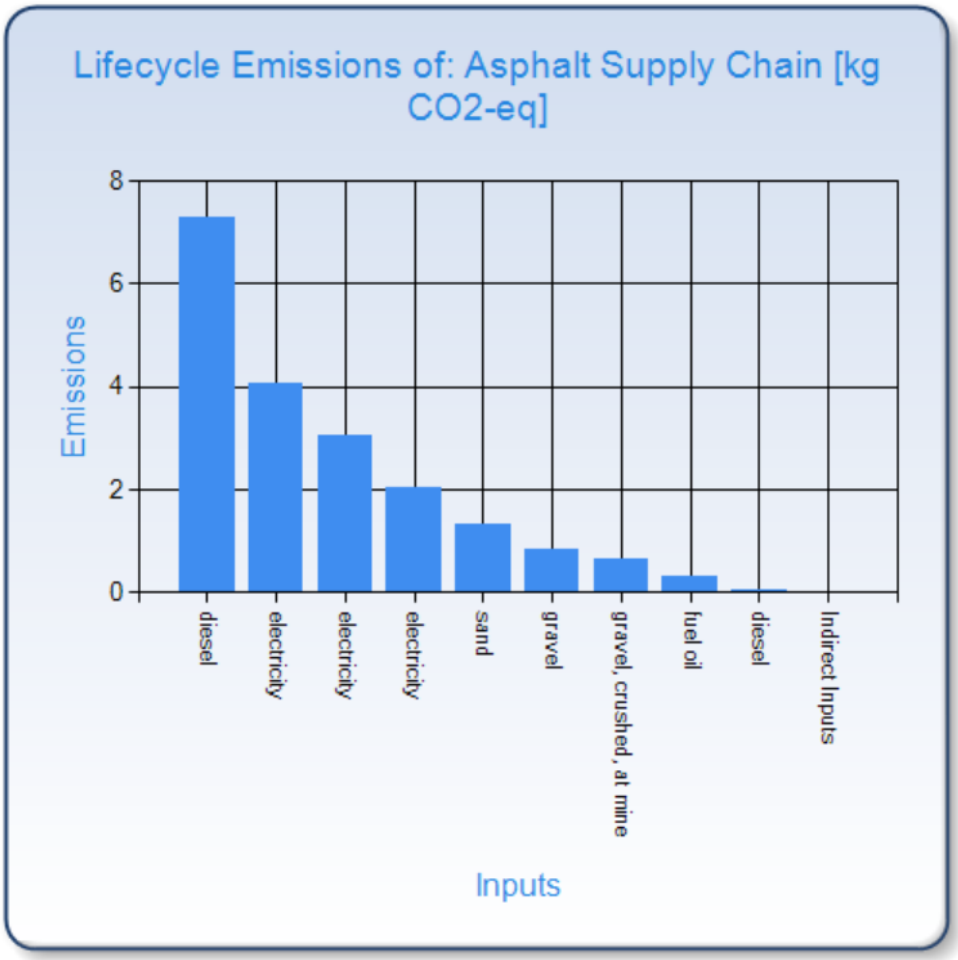
Input Name	Carbon Emissions	Emission %
diesel	7.2924	26.8%
electricity	6.0882	22.3%
electricity	6.0882	22.3%

15 Appendix G: Auto-generated report for Scenario 1

The Supply Chain Environmental Analysis Tool (SCEnAT) was used to model the Tarmac Supply Chain of Tarmac XYZ (Scenario 1) in order to evaluate the total lifecycle carbon emissions, identify carbon-hotspots and suggest possible low carbon intervention measures to address the hotspots. The results of lifecycle assessment (LCA) undertaken using the Hybrid LCA methodology are based on the environmental impacts due to global warming potential of the Tarmac Supply Chain. The total lifecycle carbon emissions were estimated to be 20.01 kg CO_2-eq/ton. This can further be divided into two main categories: process LCA impacts and indirect impacts. The process LCA impacts contributed 100.00 % of the total lifecycle impacts of the Tarmac Supply Chain. Indirect impacts associated with the supply chain were estimated to be 0.00 %. These indirect impacts arise from emissions associated with indirect inputs from the industries aggregated across 18 sectors namely: Agriculture, Forestry, Mining, Food, Textiles, Wood & Paper, Fuels, Chemicals, Minerals, Metals, Equipment, Utilities, Construction, Trade, Transport & Communication, Business services, Personal Services.



The use of the robust Hybrid LCA ensures that e those inputs that might otherwise be missed in the process LCA system, such as such as construction of commercial buildings (to account for construction of plants and related buildings), service related inputs (such as administration and business related activities), and other special purpose machineries for instance are captured. The Lifecycle Emissions of the Tarmac Supply Chain are presented below in a bar chart. It consists of all direct and indirect inputs into the LCA system, classified into different input categories.



The results of the carbon accounting module of the Tarmac Supply Chain estimated using the Hybrid methodology are translated into a supply chain carbon map to identify carbon hotspots and quantify their impacts. The following scale is used in the ranking: Very High (input box colour coded in red, indicates inputs with emissions greater than 10% of the total lifecycle emissions); High (orange; 5-10%); Medium (yellow; 1-5%); Low (green; below 1%).

Full Supply Chain Data

Input Name	Amount	Avg. Unit Cost	Emission Intensity	Carbon Emissions	Emission %
diesel	15.00litre	$1.06	0.4862	7.2924	37.2%
electricity	4.00kWh	$0.08	1.0147	4.0588	20.7%
electricity	3.00kWh	$0.08	1.0147	3.0441	15.5%
electricity	2.00kWh	$0.08	1.0147	2.0294	10.3%
sand	550.00kg	$0.73	0.0024	1.3318	6.8%
gravel	300.00kg	$0.16	0.0028	0.8435	4.3%
gravel, crushed, at mine	150.00kg	$0.16	0.0043	0.6421	3.3%
fuel oil	3.50litre	$0.03	0.0910	0.3186	1.6%

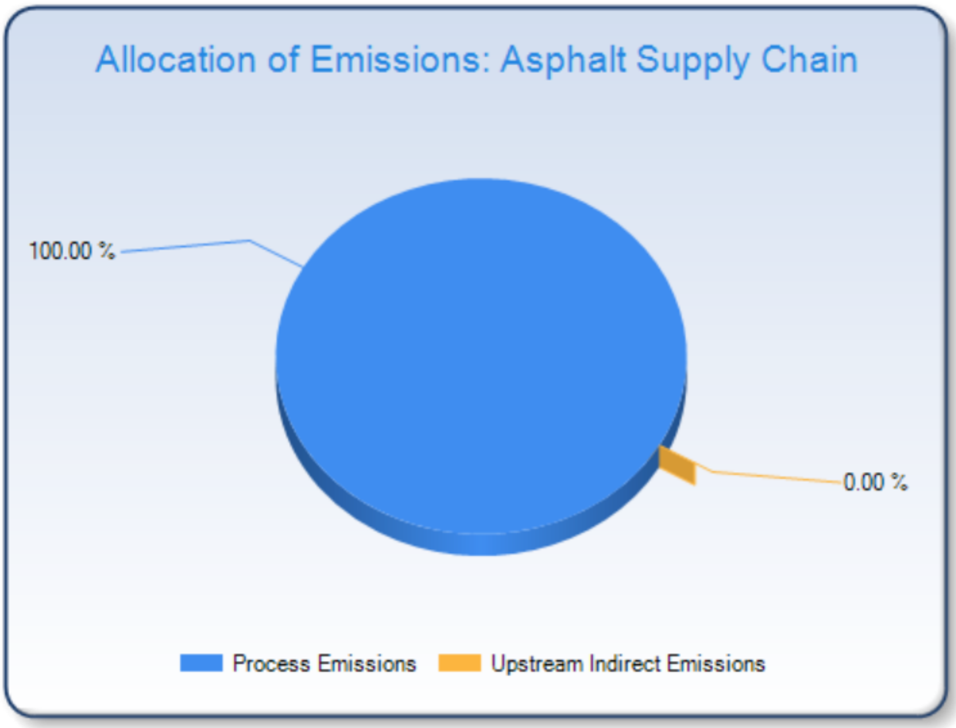
The concept of a supply chain carbon map within a complete system boundary provides insight to users and assists in the design of low carbon products and supply chains. This approach improves the effectiveness of carbon reductions in the overall supply chain by directing investment either to reduce emissions from internal processes or by helping supply chain partners and suppliers to reduce their own carbon intensity. The generated supply chain carbon maps within SCEnAT serves to provide evidence in order to adopt relevant low carbon intervention strategies in reducing carbon emissions in the Tarmac Supply Chain by targeting identified carbon hot-spots after the carbon calculation. A sample of possible interventions to target the identified carbon hot-spots is reported in the following table.

Top 3 Carbon Intensive Direct Inputs

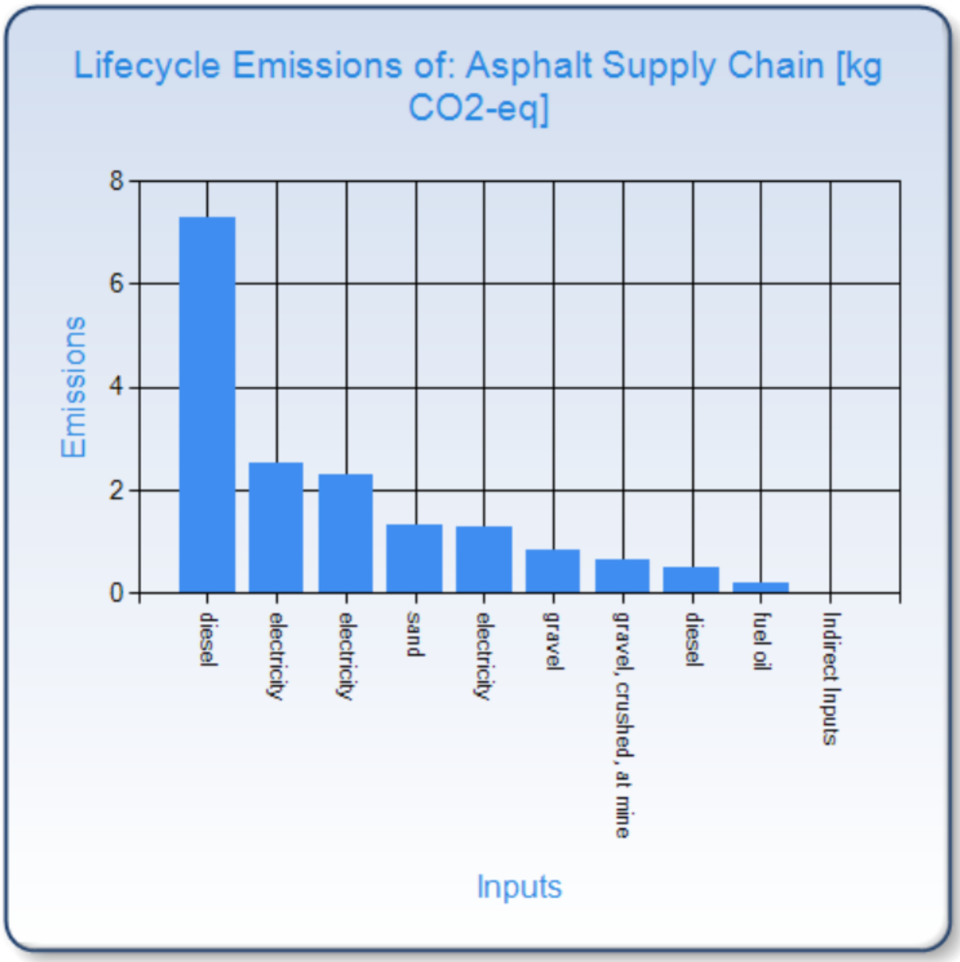
Input Name	Carbon Emissions	Emission %
diesel	7.2924	37.2%
electricity	4.0588	20.7%
electricity	3.0441	15.5%

16 Appendix H: Auto-generated report for Scenario 2

The Supply Chain Environmental Analysis Tool (SCEnAT) was used to model the Tarmac Supply Chain of Tarmac XYZ (Scenario 2) in order to evaluate the total lifecycle carbon emissions, identify carbon-hotspots and suggest possible low carbon intervention measures to address the hotspots. The results of lifecycle assessment (LCA) undertaken using the Hybrid LCA methodology are based on the environmental impacts due to global warming potential of the Tarmac Supply Chain. The total lifecycle carbon emissions was estimated to be 17.03 kg CO_2-eq/ton. This can further be divided into two main categories: process LCA impacts and indirect impacts. The process LCA impacts contributed 100.00 % of the total lifecycle impacts of the Tarmac Supply Chain. Indirect impacts associated with the supply chain were estimated to be 0.00 %. These indirect impacts arise from emissions associated with indirect inputs from the industries aggregated across 18 sectors namely: Agriculture, Forestry, Mining, Food, Textiles, Wood & Paper, Fuels, Chemicals, Minerals, Metals, Equipment, Utilities, Construction, Trade, Transport & Communication, Business services, Personal Services.



The use of the robust Hybrid LCA ensures that those inputs that might otherwise be missed in the process LCA system, such as construction of commercial buildings (to account for construction of plants and related buildings), service related inputs (such as administration and business related activities), and other special purpose machineries for instance are captured. The Lifecycle Emissions of the Tarmac Supply Chain are presented below in a bar chart. It consists of all direct and indirect inputs into the LCA system, classified into different input categories.



The results of the carbon accounting module of the Tarmac Supply Chain estimated using the Hybrid methodology are translated into a supply chain carbon map to identify carbon hotspots and quantify their impacts. The following scale is used in the ranking: Very High (input box colour coded in red, indicates inputs with emissions greater than 10% of the total lifecycle emissions); High (orange; 5-10%); Medium (yellow; 1-5%); Low (green; below 1%).

Full Supply Chain Data

Input Name	Amount	Avg. Unit Cost	Emission Intensity	Carbon Emissions	Emission %
diesel	15.00litre	$1.06	0.4862	7.2924	43.2%
electricity	2.50kWh	$0.08	1.0147	2.5368	15.0%
electricity	2.25kWh	$0.08	1.0147	2.2831	13.5%
sand	550.00kg	$0.73	0.0024	1.3318	7.9%
electricity	1.25kWh	$0.08	1.0147	1.2684	7.5%
gravel	300.00kg	$0.16	0.0028	0.8435	5.0%
gravel, crushed, at mine	150.00kg	$0.16	0.0043	0.6421	3.8%
diesel	1.00litre	$1.06	0.4862	0.4862	2.9%
fuel oil	2.13litre	$0.03	0.0910	0.1934	1.1%

The concept of a supply chain carbon map within a complete system boundary provides insight to users and assists in the design of low carbon products and supply chains. This approach improves the effectiveness of carbon reductions in the overall supply chain by directing investment either to reduce emissions from internal processes or by helping supply chain partners and suppliers to reduce their own carbon intensity. The generated supply chain carbon maps within SCEnAT serves to provide evidence in order to adopt relevant low carbon intervention strategies in reducing carbon emissions in the Tarmac Supply Chain by targeting identified carbon hot-spots after the carbon calculation. A sample of possible interventions to target the identified carbon hot-spots is reported in the following table.

Top 3 Carbon Intensive Direct Inputs

Input Name	Carbon Emissions	Emission %
diesel	7.2924	43.2%
electricity	2.5368	15.0%
electricity	2.2831	13.5%

17 Appendix I: Bibliographical Databases

Table 17-1: The 20 bibliographical databases and number of articles extracted (second search)

All Providers (Databases)	*Number of Articles*
ScienceDirect	*186*
Scopus®	*78*
Complementary Index	*33*
Academic Search Complete	*18*
Business Source Complete	*18*
Environment Complete	*13*
Supplemental Index	*11*
GreenFILE	*10*
Directory of Open Access Journals	*9*
SwePub	*4*
Emerald Insight	*4*
JSTOR Journals	*4*
PsycINFO	*3*
Art & Architecture Complete	*2*
British Library EThOS	*2*
Computers & Applied Sciences Complete	*2*
Education Research Complete	*2*
SPORTDiscus with Full Text	*1*
Oxford Scholarship Online	*1*
IEEE Xplore Digital Library	*1*

18 Appendix J: Data Collection Form

The University Of Sheffield.

University of Sheffield

Logistics and Supply Chain Management Research Centre

Data Collection Sheet: **Company XYZ**

PLEASE NOTE: Save file after filling in the form.

Enter Date
dd- mm- yyyy

[1a] **Specify Product:**

Information in the form of reports/diagrams/flow charts/company literature on detailed description of production process and supply chain of the selected chemical product has been arranged — Please Choose

[1b] Functional Unit to be used (All data supplied should be scaled to this functional Unit) — 1 | Tonne

[1c] What are the roles of Company XYZ in these Supply Chains?

Please Describe:

[2] **Materials Usage**

Please specify all the materials used to manufacture the product per year: quantities and units (Suppliers should respond to this question)

(Add more if required)

MATERIAL	QUANTITY	Units

[2] **Utilities Usage**

Please specify all the total amount of utilities used to manufacture the product (example, electricity, gas, etc) per year: quantities and units (Suppliers should respond to this question)

(Add more if required)

UTILITY	QUANTITY	Units
Electricity		
Gas		
Petrol		
Diesel		
Water		

Total Output and Allocation

[3a] What is the total amount of product processed by Company XYZ per Year — Pieces

[3b] What percentage of the total energy usage can be allocated to the specific product (this is relative to other products which are also processed by the supplier). Allocation may be done as follows: **For Petrol and Diesel:** Ratio of [Total number of each product multiplied by Average distance for delivery to customer] for all products
For Electricity: Ratio of [Total number of each product multiplied by Average time spent processing each product] for all products **For Gas:** Ratio of the total number of each product processed per year

Energy	Allocation [%]
Electricity	
Gas	
Petrol	
Diesel	
Water	

[4] **Transportation**

What is the average distance (km) travelled for delivery of raw materials to Company XYZ? Route (locations) may be listed

[5] **Waste Management**

Outline waste management sevices implemented in the processes

[6] **Any Other Information**

Please detail any other relevant information

19 Appendix K: Ethics approval and Forms

University of Liverpool Management School Research Ethics Committee

18 December 2017

Dear Mr Misopoulos

I am pleased to inform you that your application for research ethics approval has been approved. Application details and conditions of approval can be found below. Appendix A contains a list of documents approved by the Committee.

Application Details

Reference:	2156
Project Title:	Sustainability Drivers
Principal Investigator/Supervisor:	Mr Fotios Misopoulos
Co-Investigator(s):	-
Lead Student Investigator:	-
Department:	Marketing and Operations
Approval Date:	18/12/2017
Approval Expiry Date:	Five years from the approval date listed above

The application was **APPROVED** subject to the following conditions:

Conditions of approval

- All serious adverse events must be reported via the Research Integrity and Ethics Team (ethics@liverpool.ac.uk) within 24 hours of their occurrence.
- If you wish to extend the duration of the study beyond the research ethics approval expiry date listed above, a new application should be submitted.

If you wish to make an amendment to the research, please create and submit an amendment form using the research ethics

- system. If the named Principal Investigator or Supervisor leaves the employment of the University during the course of this
- approval, the approval will lapse. Therefore it will be necessary to create and submit an amendment form using the research ethics system. It is the responsibility of the Principal Investigator/Supervisor to inform all the investigators of the terms of the
- approval.

Kind regards,

University of Liverpool Management School Research Ethics Committee

J.S.Roberts@liverpool.ac.uk

0151 795 3609

Appendix - Approved Documents

(Relevant only to amendments involving changes to the study documentation)

The final document set reviewed and approved by the committee is listed below:

Document Type	File Name	Date	Version
Interview Schedule	Qualitative Questionnaire	07/12/2017	v1
Participant Information Sheet	Participant Information Sheet - v1	07/12/2017	v1
Participant Consent Form	Consent Form	07/12/2017	v1

UNIVERSITY OF LIVERPOOL

Committee on Research Ethics

PARTICIPANT CONSENT FORM

Title of Research Project: Sustainability drivers and challenges

Researcher: Fotios Misopoulos

Please initial box

1. I confirm that I have read and have understood the information sheet dated [DATE] for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my rights being affected. In addition, should I not wish to answer any particular question or questions, I am free to decline. ☐

3. I understand that, under the Data Protection Act, I can at any time ask for access to the information I provide and I can also request the destruction of that information if I wish. ☐

4. I agree to take part in the above study. ☐

______________________	________	______________
Participant Name	Date	Signature
______________________	________	______________
Name of Person taking consent	Date	Signature
______________________	________	______________
Researcher	Date	Signature

Principal Investigator: Fotios Misopoulos
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Optional Statements

- The information you have submitted will be published as a report; please indicate whether you would like to receive a copy.

- I understand that confidentiality and anonymity will be maintained and it will not be possible to identify me in any publications.

- I agree for the data collected from me to be used in future research and understand that any such use of identifiable data would be reviewed and approved by a research ethics committee.

- I understand and agree that my participation will be audio recorded and I am aware of and consent to your use of these recordings for the current research

- I understand that I must not take part if for any reason I decide so

- I agree for the data collected from me to be used in relevant future research.

- I understand that my responses will be kept strictly confidential. I give permission for members of the research team to have access to my anonymised responses. I understand that my name will not be linked with the research materials, and I will not be identified or identifiable in the report or reports that result from the research.

- I understand and agree that once I submit my data it will become anonymised and I will therefore no longer be able to withdraw my data.

Participant Information Sheet

Sustainability drivers and challenges

You are being invited to participate in a research study led by the University of Liverpool. Before you decide whether to participate, please ensure that you understand the purpose of the research and what it will involve. Please read the following information carefully and feel free to request any further information or clarification. We would like to stress that you do not have to accept this invitation and should only agree to take part if you want to. Thank you for reading this.

Research Purpose: The sustainability concept has gained great attention during the last two decades. More and more companies around the globe are becoming conscious about the environmental and social impacts of their operations. This research investigates the opinions of executives, project managers, engineers, and operations managers. Its purpose is to investigate the drivers of sustainability and the challenges that they bring in the organisations' activities.

Research Participants: We wish to interview executives, project managers, engineers, and operations managers involved in construction projects or third party logistics companies. We wish to understand their perceptions and experiences of sustainability related issues and particularly the challenges they encounter.

Do you have to take part? Participation in this research is voluntary. Should you agree to participate, you can, at a later stage, withdraw at any time without explanation. If you request, any data gathered up to that point will be destroyed.

What will happen if you take part? The researchers will interview you about your opinion of sustainable practices in your organisation/industry. The interviews will last about one hour and, with your consent, will be recorded as a part of the data collection process.

How will participants benefit from participation? The themes discussed during the interviews are those that have been identified from academic literature; this will allow you to compare the theoretical aspects of sustainability as seen by academics and contrast this with your perceptions and practical experience. You will also have the opportunity, as part of the interview process, to think and reflect on the ways in which you perceive or apply sustainability practices; this may identify areas for improvement in your daily operations. You will also be able to see, if you so desire, the final outcome of the research and what others have said on the same topic.

Confidentiality: Research participants will not have their names recorded next to direct quotes or other data. Instead, your role/position will be recorded, but not your agency/department or any other identifying information. All data will be stored securely on password-locked University servers and will be destroyed five years after the completion of this study. Where material you provide is used in subsequent reports or publications, a pseudonym will be used. Should you wish, you may have a copy of the transcript of your interview.

What will happen to the results of the study? The results of the study will be published in the form of academic journal articles. If you would like to see these publications, you may be informed and given access to them.

Who can I contact if I have further questions?

Should you have any queries or require further information, contact the researchers at the University of Liverpool, Fotios Misopoulos (fotis@liverpool.ac.uk; +44 151 794 3684).

What if I am unhappy or if there is a problem? : If you are unhappy, or if there is a problem, please feel free to let us know by contacting Fotios Misopoulos (fotis@liverpool.ac.uk; +44 151 794 3684) and we will try to help. If you remain unhappy or have a complaint which you feel you cannot come to us with then you should contact the University of Liverpool's Research Governance Officer on 0151 794 8290 (ethics@liv.ac.uk). When contacting the Research Governance Officer, please provide details of the name or description of the study (so that it can be identified), the researcher involved, and the details of the complaint you wish to make.

INTERVIEW GUIDE

Q1. Which industry sector best represents your company? (Please choose one)

Q2. What is the title of your current position within the organisation?

Q3. How long have you been employed in the organisation?

Q4. What is your organisation's total headcount?

Q5. What are the main reasons that caused your company to be involved in sustainability practices?

Q6. What are the greatest risks to your company from climate change?

Q7. Are there any opportunities to your company from climate change?

Q8. What do you believe is the status of environmental sustainability on the agenda of your organisation's top management?

Q9. What measures is your company taking to lower greenhouse gas emissions?

Q10. Do you have an environmental policy? If so, what management systems do you use?

Q11. How important would you consider having software that would assess the company's as well as the supply chain's activities carbon footprint so that it would allow for appropriate interventions to lowering them?

Q11.1 Would you be using such software if it was publicly available (free of charge)?

Q11.2 Should the government make such software freely accessible to organisations?