Product Stewardship as a Novel Sustainability Pathway for the UK Precast Concrete Industry

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PRODUCT STEWARDSHIP AS A NOVEL SUSTAINABILITY PATHWAY FOR THE UK PRECAST CONCRETE INDUSTRY

By

Abdullahi Adamu Aliyu

A dissertation thesis submitted in partial fulfilment of the requirements for the award of the degree Doctor of Engineering (EngD), at Loughborough University

September 2014

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ABSTRACT

Over the last two decades, sustainability has matured to become a societal imperative and is at the forefront of UK government policy and industry strategy. For example, the Strategy for Sustainable Construction (BERR, 2008) and Low Carbon Construction (BIS, 2012) reports have focused on encouraging more sustainable construction through reductions in energy, water and resource use. In response to such demands, the UK precast concrete industry developed a sector sustainability strategy and subsequently chose to continue activities in this area through an Engineering Doctorate (EngD) research project. The project focused on the scope for applying the principles of product stewardship (PS) as a means to mitigate environmental impacts associated with precast products, throughout the entire life-cycle of their use. Numerous PS schemes have been adopted in other industrial sectors, such as chemicals, electronics and product manufacture. One of the distinguishing features of PS is that multiple stakeholders need to take responsibility for their 'share' of environmental impacts, and that life-cycle thinking should pervade the value chain. Hence, through PS, the precast industry might be able to address not only the impacts within cradle-to-gate phases, but also develop a framework to positively act on broader, cradle-to-grave impacts.

The aim of this research was to develop a framework for embedding the principles of PS more deeply into the precast industry, creating a novel pathway towards more sustainable construction. The research commenced with a literature review to understand the key sustainability issues affecting the industry, followed by an analysis and synthesis of industry key performance indicator (KPI) data from 2006–2012. Industry participation in the research was facilitated through a questionnaire survey and interviews with senior staff within UK precast businesses. Evidence of PS practices was found to exist within the industry through responsible sourcing schemes, implementation of Environmental Management Systems and through the mitigation of various specific impacts. However, the coordinated communication of such initiatives was found to be lacking and with the advent of new European standards around Environmental Product Declarations (EPD) for construction, it was decided that the precast industry would benefit from a sector-specific EPD framework to capture and communicate its PS credentials. An EPD framework and tool was therefore developed and validated through a focus group, to establish whether an EPD can be used successfully to deliver environmental information and refine an approach such that it would accord with the principles of PS.

Further research and development arising from this research could focus on implementation and evaluation of the industry-specific EPD scheme, a mechanism to communicate and share life-cycle information amongst upstream and downstream stakeholders and a means through which stakeholder responsibility can be attributed and managed effectively.

The key findings of this research have been presented in four peer–reviewed papers (one of which is in draft) which are presented in the Appendices.

KEYWORDS

Precast concrete industry; product stewardship; sustainable construction; environmental product declarations.

PREFACE

The Centre for Innovative and Collaborative Engineering (CICE), Loughborough University in collaboration with the British Precast Concrete Federation (BPCF) established a four-year Engineering Doctorate (EngD) research programme, “Product Stewardship as a novel sustainability pathway for UK precast concrete industry”, in October, 2008 the Author was appointed as a Research Engineer (RE) to undertake a four-year EngD on the above named project. The EngD research was administered at Loughborough University and was a joint collaborative research project with the British Precast Concrete Federation (BPCF), the UK’s Trade Federation of Precast Concrete Manufacturers and a member of the Mineral Product Association (MPA).

The EngD is assessed based on submitting a thesis consisting of a minimum of three peer-reviewed academic paper publications or accepted publications, of which one must be a journal paper. This thesis contains four academic papers; two journal papers (one of which is in press and the other is in draft) and two peer-reviewed conference papers. Readers are advised that the format of this thesis requires that papers should be read in concert with the main chapters, as the contents are mutually supportive.

ABBREVIATIONS/ACRONYMS USED

BERR	Department for Business, Enterprise and Regulatory Reform
BPCF	British Precast Concrete Federation
BRE	British Research Establishment
BSI	British Standard Institution
CBI	Confederation of British Industries
CD&E	Construction, Demolition and Excavation
CIB	International Council for Research and Innovation in Building and Construction
CICE	Centre for Innovative and Collaborative Construction Engineering
CIRIA	Construction Industry Research and Information Association
CISCF	Concrete Industry Sustainable Construction Forum
CPA	Construction Products Association
CSR	Corporate Social Responsibility
CT 2010	Concrete Targets 2010 Scheme
CT 2015	Concrete Targets 2015 Scheme
DCLG	Department for Communities and Local Government
DEFRA	Department for Environment, Food and Rural Affairs
DETR	Department for Environment, Transport and Regions
DfE	Design for Environment
DTI	Department of Trade and Industry
ELV	End of Life Vehicles
EngD	Engineering Doctorate
EPA	Environmental Protection Agency
EPD	Environmental Products Declaration
EPR	Extended Producer Responsibility
EU	European Union
GHG	Green House Gas
GPS	Global Product Strategy
HP	Hewlett Packard
HSE	Health, Safety and Environment
IBU	Institute for Construction and Environment
ICCA	International Council of Chemical Associations
ICE	Institution of Civil Engineers

IEA	International Energy Agency
ISO	International Organisation for Standardisation
IUCN	International Union for Conservation of Nature
KPI	Key Performance Indicators
LCA	Life Cycle Analysis
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Analysis
LCM	Life Cycle Management
LTIFR	Loss Time Injury Frequency Rate
LTIs	Lost Time Injuries
MPA	Mineral Products Association
NEPIs	New Environmental Policy Instruments
NGOs	Non-Governmental Organisations
OICA	International organization of Motor Vehicle Manufacturers
PC	Product Category
PCR	Product Category Rules
PS	Product Stewardship
RCGC	Responsible Care Global Charter
RE	Research Engineer
RIDDOR	Reporting of Injuries, Diseases and Dangerous Occurrences Regulations
RSM	Responsible Sourcing of Materials
SAICM	Strategic Approach to International Chemicals Management
SCF	Sustainable Construction Forum
SME	Small or Medium Enterprise
SSC	Strategy for Sustainable Construction
UK	United Kingdom
UNEP	United Nations Environmental Programme
US	United States of America
WBCSD	World Business Council for Sustainable Development
WCED	World Commission for Environment and Development
WEEE	Waste Electric and Electronic Equipment
WRI	World Resource Institute

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Paper 2 (Appendix B)

Aliyu, A. A., Glass, J., Price, A.D.F and Elhag, H. K. (2012). Assessing the potential of product stewardship for the UK precast concrete industry. Proceedings of *Concrete in the Low Carbon Era Conference*, University of Dundee 2012: Dundee (Scotland) 2012: pp374 - 386. ISBN 978-0-9573263-0-9.

Paper 3 (Appendix C)

Aliyu, A. A., Glass, J., Clarke, M. A, Elhag, H. K and Price, A.D.F. (2013). Conceptual and structural components of product stewardship in the UK precast concrete industry. *International Journal of Sustainable Construction*. (In press 2013, Vol.2 Issue 1).

Paper 4 (Appendix D)

Aliyu, A. A., Glass, J., Clarke, M. A, Elhag, H. K and Price, A.D.F. (2012). Exploring EPDs as a mechanism of enhancing Product stewardship in the UK precast concrete industry. *Journal for Cleaner Production* (*In draft*).

1. INTRODUCTION

The Centre for Innovative and Collaborative Engineering (CICE), Loughborough University, in collaboration with the British Precast Concrete Federation (BPCF) established a four year Engineering Doctorate (EngD) research programme in October 2008 titled: *“Product stewardship as a novel sustainability pathway for the UK precast concrete industry”.* This chapter introduces the background of the research area and states the aim and objectives of the EngD research. The chapter also contains an overview of the industrial sponsor – British Precast Concrete Federation (BPCF or British Precast) and the general structure of the thesis which has five chapters as part of the requirements for the fulfilment of the award of Doctor of Engineering at Loughborough University. The appendices of the thesis include peer-reviewed conference papers, a journal paper, a questionnaire survey template and interview questions for the precast concrete industry and other research survey results and template documents generated as part of the primary data of the EngD.

1.1 BACKGROUND TO THE RESEARCH

The British Precast Concrete Federation (BPCF), the umbrella body for the UK precast concrete industry, devised a sustainability programme “*More from Less*” in 2004 to address the sustainability issues and activities of the industry. Still on-going, the programme was purposely aimed at measuring, improving and promoting the environmental, social and economic credentials of precast concrete products in the UK. As a result, a sector sustainability strategy was developed and implemented to move the precast concrete industry forward (Holton, 2009). The sector sustainability project started in 2004 and was completed in 2008. Following the successes recorded from the *“More from Less”* programme within the precast concrete industry, in 2008, and in collaboration with Loughborough University, the BPCF approved the continuation of another project titled *“Product Stewardship as a Novel Sustainability Pathway for the UK Precast Concrete Industry”.* This project explores, and is focused on developing a framework to embed the principles of product stewardship (PS) into the UK precast industry, thereby creating a novel pathway towards more sustainable construction. PS schemes help all stakeholders within businesses, companies, organisations and multinational corporations to mitigate the environmental and social impacts associated with their products throughout the entire life cycle of the product from ‘*cradle to cradle’* by taking responsibility to address such impacts. Based on this, the aim and objectives of the study are set in the following section.

1.2 THE SPONSORS

1.2.1 Academic Sponsors

The Engineering and Physical Sciences Research Council (EPSRC) and the Centre for Innovative and Collaborative Construction Engineering (CICE) under the School of Civil and Building Engineering, Loughborough University are the Academic sponsors of this EngD research.

1.2.2 The Industrial Sponsor

The British Precast Concrete Federation (BPCF), commonly known as British Precast, is the trade federation of precast concrete manufacturers operating in the United Kingdom and it was the Industrial Sponsor for the research described in this thesis. Its main parent body is the Mineral Products Association (MPA) which is the "UK's trade association for the aggregates, asphalt, cement, concrete, dimension stone, lime mortar and silica sand industries" (MPA, 2014).

As a national industry, the federation is comprised of precast groups, companies and other bodies. The main aims of the federation are "*to promote precast concrete in the construction market and to disseminate information, through a range of industry representation and by shared knowledge, to add value to its member companies*" (BPCF, 2013:1). As a federation, the BPCF helps "*to improve the business environment, both short and long term, for the £2.6 billion concrete products industry in Great Britain and Northern Ireland*" (BPCF, 2011:2). The BPCF has a federated structure with 13 focused product sector groups which consist of product manufacturers and affiliated bodies:

1. Aggregate Blocks [CBA]
2. Aircrete Products [APA]
3. Architectural Cladding [ACA]
4. Block Paving Contractors [Interlay].
5. Box Culverts [BoxCA]
6. Construction Packed Products Association [CPPA]
7. Modern Masonry Alliance [MMA]
8. Paving and Kerb [Interpave]
9. Pipeline Systems [CPSA]
10. Precast Floors [PFF]

11. Railway Sleepers [CSMA]
12. Roof Tiles [CTMA]
13. Structural Precast [SPA]

The BPCF as an organisation geographically represents the whole of the UK, and from the production point of view its membership represents all precast concrete components produced in factories in the UK (BPCF, 2009). Although not all UK manufacturers belong to the federation, it is estimated that 65-70% (14 million tonnes approximately) of UK production is covered by the federation's membership. The BPCF can trace its roots back to 1918 (BPCF, 2013) when entrepreneurial engineers and builders realised the importance of high quality and the economic advantages offered by casting concrete with the use of machines (Clarke, 2003). In 2008, UK's precast concrete production stood at over 36 million tonnes of products annually, worth in excess of £2.3 billion at the time (Holton, 2009). There were over 800 precast concrete companies in the UK (Sustainable Concrete, 2009) with around 23,000 employees (BIBM, 2008) and more in the upstream and downstream sector of the UK economy. Estimate suggests that in 2013, the precast concrete industry produced 20 million tonnes.

There is no exact figure of the current number of employees for the industry; however current estimates in 2013 suggest the precast concrete industry produces around 18 million tonnes of precast concrete and has an estimated 12,365 as the total number of employees (Elhag and Richards, 2013). The reduction in production is a direct result of the economic recession of experienced in 2008. The precast concrete industry forms part of the wider construction industry which used to employ seven per cent of the UK population (BCA, 2006) and accounted for eight per cent of Gross Domestic Product (GDP) (BERR, 2008). The precast concrete industry in the UK is therefore an important sector of the UK construction products industry which includes building, civil engineering, construction materials and products, and associated services (Holton *et al.*, 2008). According to the Construction Products Association (CPA), the largest among the four different, but related, activities is the construction materials and products, which has a total annual turnover of more than £40 billion (CPA, 2007).

1.3 AIM AND OBJECTIVES

The overarching aim of the Engineering Doctorate (EngD) programme is driving innovation in the engineering/applied science industry by demonstrating excellence in solving technical, managerial and business problems in an industrial context (CICE, 2014) through the following specific aim and objectives. In this research, the specific research aim and supporting objectives are set out below and set in context in Figure 1.1, 1.2 and Table 1.1 which follow this section.

1.3.1 Aim

This aim of this research was to embed the principles of PS through developing an environmental products declaration (EPD) framework for the UK precast concrete industry, thereby creating a novel pathway towards sustainable construction.

1.3.2 Objectives

In support of the above aim, and to meet the aim of the research, five research objectives were agreed by the supervisory team and carefully identified as, to:

1. Understand the UK precast concrete industry's key sustainability issues and identify its most significant impacts;
2. explore the possible characteristics and implications of implementing product stewardship within the precast concrete industry;
3. analyse the sustainability performance of the precast concrete industry through its reported key performance indicators (KPI);
4. investigate the use of EPD within the precast industry as a means of implementing PS; and, develop and validate a framework for introducing EPDs in the UK precast concrete industry.

The reason for these research objectives is to help the precast concrete industry to improve on its current sustainability strategy (Holton, 2010), environmental performance and profile through a robust and coherent product stewardship and life cycle management approach.

All the five research objectives where carefully chosen under the guidance of the supervisory team. This was achieved through: State–of-the art literature reviews, site/ factory visits, review of UK government policies and reports on sustainable construction and low carbon construction issues as well as the concrete and precast concrete industry reports, the role precast concrete plays towards achieving sustainable construction, vision and priority areas informed the decision of choosing the said objectives. These were further confirmed through industry surveys; attendance in over 15 meetings of the Sustainability and Environment Committee (SEC) over four years. Objectives related to the precast concrete industry reflect the workings, production, operation and aspiration of the industry. This was corroborated by the industry during the course of surveys and feedback received from the SEC members of British Precast. These objectives are further explained in Chapter Three Section 3.3 pages 53 to 56. Figure 1.1 shows a detailed research map showing the aim and how all the five research objectives where met. These provide analysis, discussion and explanation of how the objectives of the EngD research where conceived, developed and how they were met in the EngD thesis. All these objectives where met as explained in the next sub-section

1.3.3 Meeting the research objectives

Figure 1.1 shows a detailed research map on how the aim and objectives of the EngD thesis were met through specific research work and academic papers or outputs. A combination of two peer reviewed conference papers, one journal paper (in press) and a draft journal paper forms part of the research outputs.

What shaped the decision to choose the research methods used in this EngD research was taking into cognisance of the core principle behind the EngD; British Precast Concrete Federation's (BPCF) i.e. industrial sponsor's requirements and key priorities for the EngD and the research brief given to the Research Engineer (RE). The research methods used for the EngD research where carefully selected based on the following;

1. the collaborative nature of the research being industry based and being sponsored by British Precast;
2. the need to identify and solve key managerial problems within the UK precast concrete industry in this case accessing the potential product stewardship could offer to improve the sustainability of the precast concrete industry;
3. the need to understand the industry's needs with regards to sustainability and the management of the precast industry's key environmental and social impacts as well as to understand the industry's perception and readiness to improve sustainability and implement product stewardship; and,
4. commitment of the industry to support and sponsor field work, carry out Life Cycle Assessment (due to it being time consuming and its cost implications) and the RE's, research time frame and financial support.

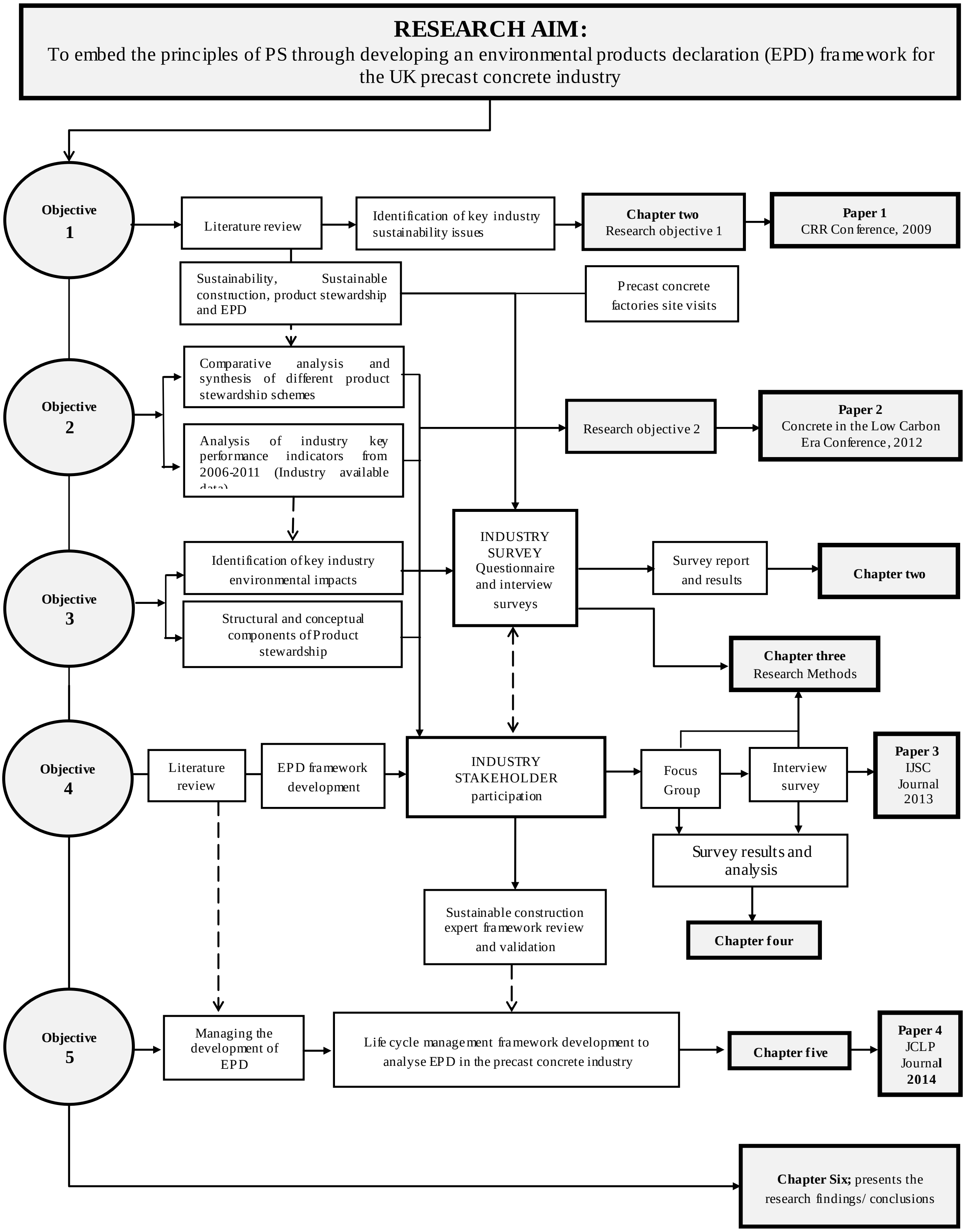

Figure 1.1: Detailed research map showing the aim and how all the five research objectives where met.

1.4 STRUCTURE OF THE THESIS

This EngD thesis comprises six chapters; these are summarised below.

Chapter One presents the general introduction and background to the EngD research. The chapter explains the aim and objectives of the research, the overarching aim of the EngD programme and the structure of the thesis, giving a brief overview about the industrial sponsor.

Chapter Two provides a general overview on the primary research area of the EngD thesis. A review of existing academic and industry literature was conducted covering sustainability, sustainable construction and issues within the precast industry, selected PS schemes and initiatives were reviewed and areas identified as key to the EngD research earmarked.

Chapter Three sets out the research methods which are pertinent to this project. The chosen methods adopted for the EngD research, which include a combination of qualitative and quantitative research methods, are reviewed in this chapter.

Chapter Four contains details of the research undertaken in meeting the overall aim and objectives of the EngD. The chapter also encompasses five work packages with each work package consisting of key research findings and outputs from peer-reviewed papers. A summary of the work packages is shown in Table 1.1, followed by Figure 1.1 showing a map of the four-year journey.

Chapter Five presents a framework specifically for managing the development of Environmental Product Declarations (EPD) for precast concrete manufacturers and their trade federation British Precast. The framework includes; an Eco-point Index Environmental Impacts (2EI) Calculator, Company - level EPD management data, EPD technical report and a combined company portfolio of EPD.

Chapter Six presents the research findings, conclusions and discusses their possible implications for the industrial sponsor and the UK precast concrete industry. It also includes outcomes from the research, a critical evaluation of the research and recommendations for further study in the field. The chapter also discusses the recommendations for the industrial sponsor and the concrete industry and also identified areas of further academic and industrial research.

Appendix A comprises Paper One a published peer-reviewed conference paper that supports the EngD research conducted and should be read in conjunction with the thesis. While Appendix A to C are already published, Appendix D is in draft and is based on the content on EPDs presented in Chapter 4.

Appendix B consists of Paper Two which assesses the potential of PS within the industry.

Appendix C consists of Paper Three focused on conceptual and structural components of PS for the precast concrete industry

Appendix D consists of Paper Four which explores EPDs as a mechanism for enhancing PS in the UK precast concrete industry

Appendix E comprises industry interviews, questionnaire survey

Appendix F consists of Focus group and short questionnaire survey analysis

Appendix G consists of four models developed from the study of selected industries with PS schemes or initiatives.

Appendix H shows EPD creation stages according to the Institute for Construction and Environment (IBU).

Appendix I present an example of Cement EPD from LCA results which is the closest and latest EPD example related to the UK precast and concrete industry.

Appendix J presents a flier with the summary of the EngD research project.

Synopsis of the papers can be found in section 1.4. All papers should be read in conjunction with the EngD thesis.

Table 1.1: EngD research conducted

Research aim: To develop a framework to embed the principles of product stewardship (PS) into the UK precast industry, thereby creating a novel pathway towards more sustainable construction.

Work packages (WP)	Research objectives	Research tasks/ activities	Research method used	Research outcome	Chronology	Status
WP 1	Establishing the context of the research area	1. Understanding the research area; the UK precast concrete industry, sustainability and product stewardship	Literature review/ content analysis	**Literature review document**	**Completed January 2009**	**Completed**
		2. Identification of key sustainability issues within the context of the precast concrete industry				
		3. Establishing the need for product stewardship to improve the sustainability profile of the precast concrete industry		**Paper 1** - The need for a product stewardship scheme to improve sustainability in the UK precast concrete industry.	**Completed July 2009**	
WP 2	Analysis and synthesis of different product stewardship schemes and the possibilities of implementation in the precast concrete industry	4. Comparative analysis and synthesis of different product stewardship schemes and analysis of industry key performance indicators from 2006-2011	Interview survey and Key performance indicators analysis	**Paper 2** – Assessing the potential of product stewardship for the UK precast concrete industry	**Completed August 2011**	
WP 3	Mapping of environmental and social impacts	5. Identification of the UK precast concrete industry's key environmental and social impacts	Literature review			
WP 4	Identifying key components of PS for the industry	6. Identification of key structural and conceptual components of product stewardship in the UK precast concrete industry and gauging the industry's understanding of PS, its acceptability, possible operation, prospects, benefits, challenges and barriers	Questionnaire survey and interviews	**Paper 3** – Conceptual and structural components of product stewardship in the UK precast concrete industry	**Completed February 2012**	
WP 5	Developing an Environmental Products Declaration (EPDs) framework to embed the principles of product stewardship (PS) in the UK precast industry	7. Evaluating, designing and formulating an EPDs framework for the industry	Focus groups/ Survey and interviews	**Paper 4 -** Developing an EPDS framework for the UK precast concrete industry	**February 2013**	
Completion	Reporting of key research findings	8. Dissemination and publication of key research outcomes	EngD Thesis	**Completion of research -** EngD project thesis	**January 2013**	

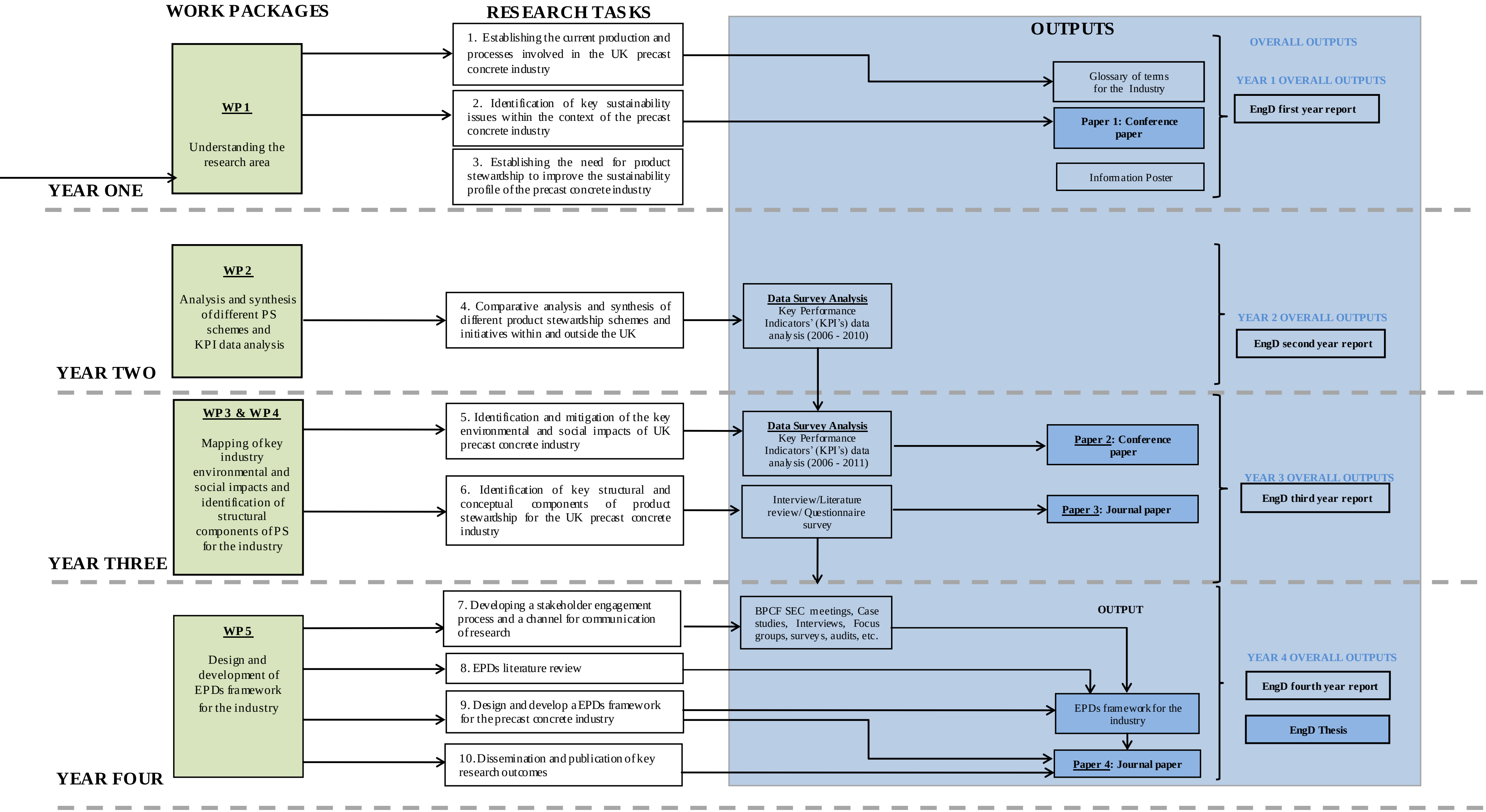

Figure 1.2 EngD Thesis Map

1.5 SYNOPSIS OF PAPERS

This section provides an outline of the peer-reviewed journal and conference papers already published, in press and in draft. Table 1.2 provides a summary of all the papers written based on primary and/or secondary research sources; it includes the paper identification and the corresponding paper appendix, the title of the paper, paper type, i.e. journal or conference, paper description and current status. The papers form an integral part of the thesis and should be read in conjunction with the thesis; they can be found in Appendices A to D.

Table 1.2 List of peer-reviewed papers

Paper ID	Title	Journal/ Conference	Description	Status
Paper 1 -Appendix A	The need for a product stewardship scheme to improve sustainability in the UK precast concrete industry.	Proceedings of the Corporate Responsibility Research (CRR) Conference, Vaasa, Finland, 2009	This is a visioning paper for the industry on how to improve sustainability through product stewardship (PS). It introduced the concept of PS, highlighted the significance of developing a PS scheme for the industry, explored its business value and explained why PS will serve as the next step forward for the industry to take voluntarily. It also identifies useful lessons for the sectors which are intending to develop or deliver a PS scheme.	Published
Paper 2 Appendix B	Assessing the potential of product stewardship for the UK precast concrete industry	Proceedings of the Concrete in the Low Carbon Era Conference, Dundee, 2012	This is the case-making paper for PS within the UK precast concrete industry. It provides a sound basis from which the industry could develop a sector-wide approach to PS, such that precast manufacturing companies can further improve performance against key environmental and social indicators and so enhance their competitiveness. It draws conclusions about impacts, stakeholder responsibilities, drivers and barriers and mechanisms.	Published
Paper 3 Appendix C	Conceptual and structural components of product stewardship in the UK precast concrete industry	International Journal for Sustainable Construction, 2013 (accepted and in press)	This paper consists of an analysis of 2006 to 2010 key performance indicators of the UK precast concrete industry and findings from 12 industry interviews. Manufacturers' understanding of PS, its potential areas of operation and implementation were investigated. Potential gaps in the sustainability management of these companies were identified and possible PS options were assessed. The paper concludes with a discussion of whether there is any synergy between PS and existing industry initiatives on sustainable construction.	In press
Paper 4 Appendix D	Developing a EPD framework for the UK precast concrete industry	Journal for Cleaner Production, (in draft)	This paper explores the potential of an industry approach to the communication and reporting of PS and life-cycle management information through the development and operation of a precast concrete sector EPD scheme. It further explores what a possible scheme format should look like, and assesses the main challenges and factors associated with the implementation of a successful EPD labelling scheme. An EPD framework for the industry is also included.	In draft

1.6 SUMMARY

This chapter introduces the thesis and summarised the background of the research. It also outlined the aim and objectives, research map, the thesis map, synopsis of peer-reviewed research papers and a general overview about the industrial sponsor. A detailed explanation was provided on how the research aim and objectives were developed and met. The next chapter gives an overview of the general subject area.

2. UNDERSTANDING SUSTAINABILITY, SUSTAINABLE CONSTRUCTION, PRODUCT STEWARDSHIP AND ENVIRONMENTAL PRODUCT DECLARATIONS

2.1 INTRODUCTION

This chapter provides an overview of relevant literature pertaining to the general context of the research, i.e. sustainable construction, including a discussion of how key concepts such as sustainability are understood and interpreted within the UK construction industry and the precast concrete industry. More specifically, the chapter considers the primary research area of the EngD thesis, i.e. product stewardship (PS). A review of existing academic and industry literature is used to identify key dimensions and specific definitions of PS and a range of different perspectives and approaches towards PS. The chapter establishes that sustainability has been well received by the UK precast concrete industry. This conforms to the overall strategy of the UK concrete industry and government targets towards achieving sustainable construction. With regards to the concept of PS, the chapter recognised that there are numerous definitions of PS to different companies, organisations, and government's etc. However, there is a general agreement that PS involves the taking of responsibility by product manufacturers and stakeholders to mitigate the environmental and social impacts of their products and service. The chapter concludes with a general overview of EPD as a successful communication tool for relaying environmental information of products and services; which can be used by the precast industry to communicate its environmental credentials and information of its products.

2.2 A BRIEF OVERVIEW OF SUSTAINABILITY

Over the last two decades, sustainable development has become a priority, and a major concern for all in the construction industry, with the concept of sustainability emerging as a buzzword (CIOB, 2009: 1). However, the concept is vague (Mebratu, 1998: 49) and the term has numerous definitions in articles, journals, books and in other sources from different fields of study. The most accepted definition (but not without criticism) is that from the 1987 '*Our Common Future*' Report by the World Commission for Environment and Development (WCED) popularly known as the Brundtland Report which is that '*development that meets the needs of the present without compromising the ability of future generations to meet their own* *needs'* (WCED, 1987: 43). Yet there are many different views of the definition, meaning and goal of sustainable development. It is a widely-contested term and the concept can be seen an oxymoron (Aysin, 2008, cited in Williams and Dair, 2007; Hopwood *et al.*, 2005; Rassafi*et al.*, 2006; Redclift, 2005; Springett, 2005; Yanarella and Bartilow, 2000). That said, sustainability is generally considered to fuse environmental, social and economic issues into a developmental paradigm (Baker, 2006), as shown in Figure 2.1.

Figure 2.1: The three pillars of sustainable development. From left to right, the theory, the reality and the change needed to better balance the model (Adams, 2006).

As a result, the subject has an interdisciplinary nature. Cruickshank and Fenner (2007: 112) explain that the primary elements of sustainable development can be seen as a nested system, as shown in Figure 2.2. This system consists of the environment, the society and the economy; the environmental system is the envelope and the rallying point, in that it serves as the context within which everything else is set.

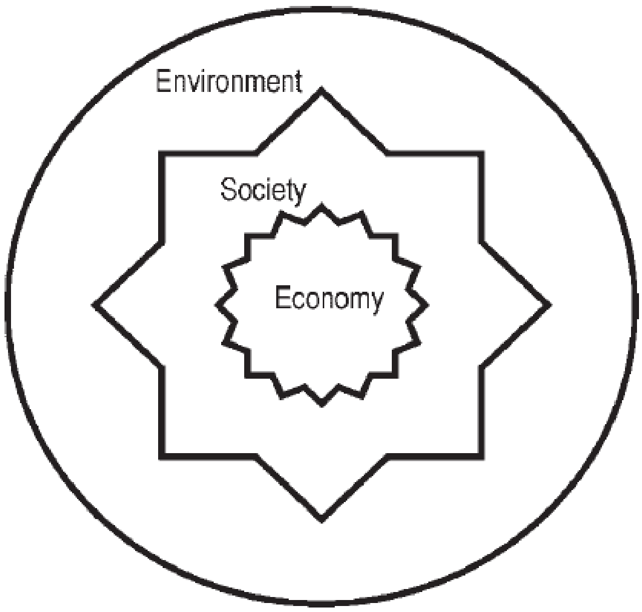

Figure 2.2: Elements of sustainable development as a nested system (Cruickshank and Fenner, 2007:112).

This is a useful theoretical model, but also a framework with pragmatic value for organisations to understand, interpret and implement their responses to national and international sustainability initiatives. However, the way in which it is interpreted and applied may vary between different organisations, industries and regions. The context and significance of these models in figure 2.1 and figure 2.2 may vary or be dependent on particular goals, objectives or mission of an individual, company, organisation, national approach or an international approach or global front. For example in the precast concrete industry, a sustainability strategy exist which focused on the environmental management, impact and performance of products, services and the whole industry. The social aspect of sustainability for the industry covers all key areas that have impacts to the industry staff/ employees and the communities. All these, have an economic component for their application or vice-versa. This sits within the realm of environmental, social and economic pillars of sustainable development – hence the following sections explore how sustainability is understood within UK construction and the concrete sector specifically.

2.2.1 SUSTAINABILITY IN THE CONSTRUCTION INDUSTRY

CIRIA (2001:9) defines sustainable construction as the application of sustainable development to the construction industry, where as Kibert (2013: 8) defines sustainable construction as *"……the creation and responsible management of a healthy built environment based on resource efficient and ecological principles".* His definition has also been adopted by the International Council for Research and Innovation in Building and Construction (CIB). According to DETR (1999), sustainable construction involves the balancing of four key elements of sustainable development:

- effective protection of the environment;
- prudent use of natural resources;
- social progress which recognises the needs of everyone; and,
- maintenance of high and stable levels of economic growth and employment.

The construction industry makes a significant contribution to the social and economic objectives of sustainable development, but it also has an environmental impact. Construction has been recognised as "one of the largest end users of environmental resources and one of the major polluters of man-made and natural environments" (Ding, 2008). As such, in the UK, sustainable construction has become a significant component within the UK government policy and strategy portfolio. Through a range of documents, a UK government position on sustainable construction has slowly evolved (e.g. BERR, 2008, 2009; DEFRA, 2005; DETR, 1998a; 1998b; 1999; 2000; DTI, 2004; Murray and Langford, 2003). It is driving the industry to adopt more sustainable practices leveraging an increasing pressure from stakeholders and business requirements from investors and consumers to see a more sustainable construction industry. One of the most high-profile document that has guided the industry towards more sustainable construction is the Strategy for Sustainable Construction (BERR, 2008), which clearly highlighted areas that demand attention by setting targets against specific sustainability issues; these included climate change mitigation, climate change adaptation, materials, water, waste and biodiversity.

The most recent report "Construction 2025: strategy" (BIS, 2013) is a joint government and industry strategy which focuses on the future of the UK construction industry. The report sets out a clear vision and plan for both government and industry on working together to foster and promote long-term strategic action on key growth markets in:

- Smart technologies;
- Green construction ; and,
- Overseas trade.

An example of how the targets have been addressed and have since evolved can be found in the approach to climate change mitigation. Initially, the government made a commitment to a 60% cut in the Climate Change Act, but it was recognised as one of the most important areas for addressing sustainable development and so the targets were revised to an 80% cut in greenhouse gas emissions by 2050 (based on 1990 baseline year) and 34% by 2020. Presently, targets for zero-carbon or carbon-neutral homes and schools, public sector non-domestic buildings and other non-domestic buildings now form part of the UK's Low Carbon Transition Plan (BERR, 2008; 2009). In September 2009, the UK Government established an Innovation and Growth Team to review the UK construction industry in order to ensure that the industry is '*fit for purpose in delivering the low carbon future'* (BIS, 2012: 1). A response to the SSC latterly came in the form of 'The Low Carbon Construction Action plan' - which focused on three key points (BIS, 2012: 4):

1. demonstrating the benefits and opportunities of low carbon construction through leadership and cooperation across the private and public sectors;
2. creating greater clarity in a complex landscape, enabling the industry to better understand the opportunities that will be available to them in the future; and,

3. ensuring that we have the right framework of incentives and interventions to enable the market to flourish and the right levels of skills, research and innovation to enable and support growth.

Hence, the government position emphasises reducing carbon emissions as a fundamental component of progress towards sustainable development and as such the various parts (sectors) of the UK construction industry have been encouraged to formulate their own approaches based on this carbon focus, not forgetting the other parts of the Strategy for Sustainable Construction, including waste and water consumption – the latter of which has assumed comparatively greater importance in recent months (BERR, 2008). The next section considers how the UK concrete industry has responded to this agenda.

2.2.2 SUSTAINABILITY, THE CONCRETE INDUSTRY AND THE SUPPLY CHAIN

To understand the concept of sustainability in the UK concrete industry it is paramount to look at the whole concrete industry supply chain structure and general organisation, the scope of which and their respective outputs (in million tonnes) is presented in Figure 2.3.

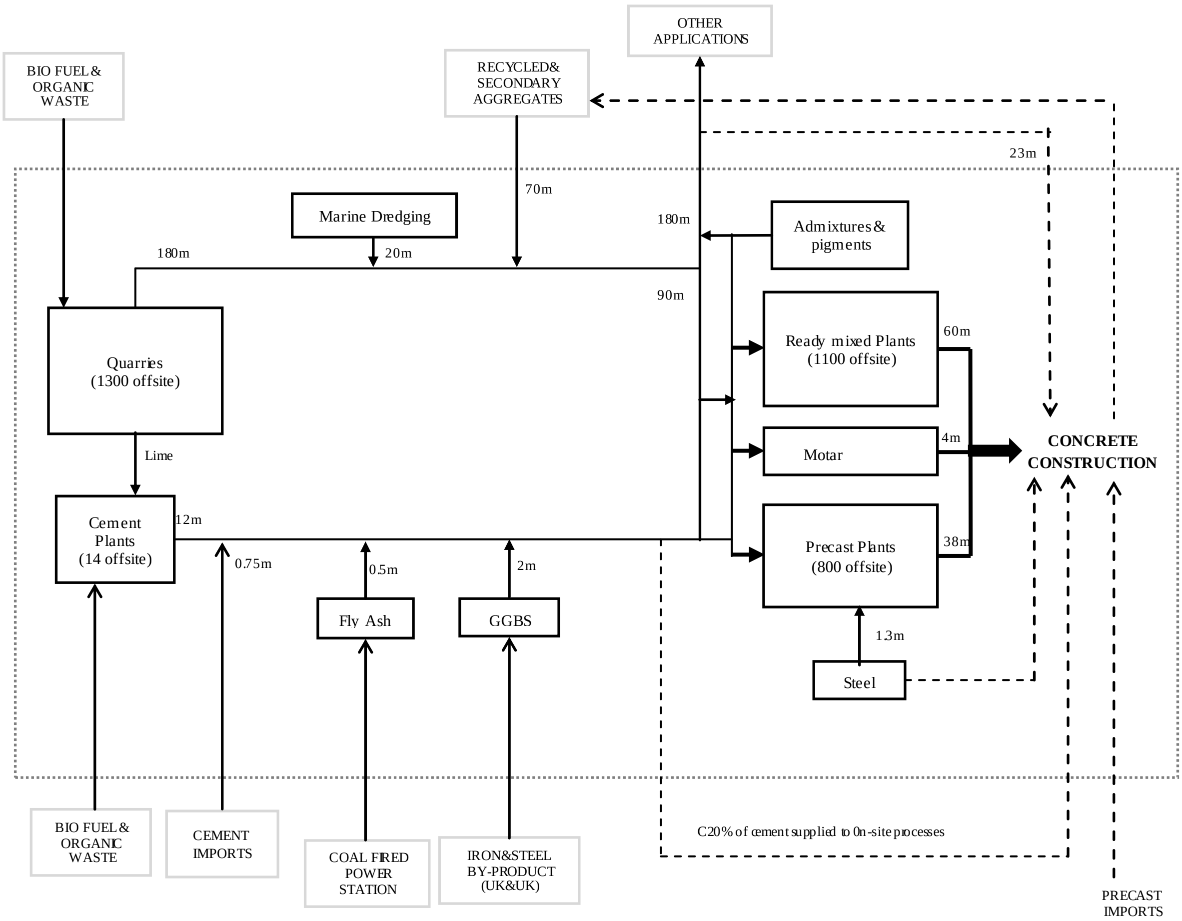

Figure 2.3: A modified concrete industry and its various supply chains (Optimat, 2008: 10).

The matrix of different entities and industries shown above together forms the UK concrete industry, but a useful distinction can be drawn between those parts of the industry which operate on site (i.e. construction) and off-site; the ten major off-site sectors within the industry are shown in Table 2.1.

Table 2.1: Concrete supply chain off-site sectors (CISCF, 2008)[1].

Source (s)	Processes
Aggregates extraction	Extraction of aggregates from quarries and through marine dredging
Manufacture of cement	Portland cement manufacture (CEM I) with the use of minor additional constituent and primary raw materials
Manufacture of additional cementitious materials	Ground granulated blast furnace slag (GGBS) and fly ash. The raw material are other industries' by-products
Manufacture of factory-made composite cements	By processing CEM 1 with secondary cementing material such as GGBS, fly ash or limestone fines
Manufacture of steel	Reinforcing bar for concrete
Speciality chemicals	To improve the processing and properties of concrete mixtures(cement admixtures)
Off-site preparation	Semi-finished products like ready-mixed concrete
Off-site manufacture	Finished precast concrete products

Despite its inherent breadth and complexity, the entire UK concrete industry has agreed a set of targets relating to sustainable construction, which align with the SSC (Optimat, 2008). A set of priorities were also identified in a sustainable development strategy for the UK concrete industry, also known as the 'Optimat Report' (Optimat, 2008). The strategy has 14 KPIs and four priority areas (DEFRA, 2005):

- sustainable consumption and production;
- climate change and energy;
- natural resource protection and enhancing the environment; and
- creating sustainable communities.

[1]NB: the production of recycled and secondary aggregates supply chains are excluded here, as these are typically processed by the waste management industry (Optimat, 2008).

Within the strategy, the UK concrete industry also committed itself to continuous performance improvement, measurement and reporting of data against performance; and, based on the success of this approach, the strategy was recently extended to 2020.

2.2.3 THE ROLE OF PRECAST CONCRETE IN SUSTAINABLE CONSTRUCTION

The precast concrete industry over the years has been a major contributor towards achievement of sustainable construction in the UK. Over the last decade, a series of initiatives and programmes devised by precast concrete companies and British Precast, the trade federation of precast concrete manufacturers has helped the industry in terms of economic growth through investment in resources and manufacturing facilities; environmental protection for example the protection of British coastlines with precast concrete products; social progress through the use of precast concrete in urban and regeneration projects (building infrastructure, public and private buildings e.t.c); and the prudent use of natural resources through waste reduction for example the use of recycled materials (British Precast, 2014). A full chronological account of the precast concrete's industry progress on sustainability has been discussed by Aliyu *et al.*, (2009) see (appendix a paper 1).

Over the last ten years, the industry through its "*More from Less*" sustainability programme has helped precast concrete companies understand and incorporate sustainability principles within manufacturing operations and other related activities for example; the Precast Industry sustainability charter was launched in 27th November, 2007 to help member companies to go beyond legislation and take voluntary actions by making all their products and operations more sustainable (BPCF, 2011). The key principles in the charter also relates to the work of Holton (2008) that developed 16 set of sustainability principles facing the industry (see figure 4.1). For companies that signed up to the charter, they agreed on set of guiding sustainability principles and agreed on a set of targets. Since 2006 to date performance measurements through the annual Key Performance Indicators (KPI) data monitoring have been conducted to map out environmental and social impacts (see table 4.1). In May, 2011 as part of the "Raising the bar initiative", all full member companies have to sign up to the charter as well as the Concrete Targets 2015 Health and Safety scheme which is an industry wide initiative to improve the industry health and safety standards and performance (BPCF Charter, 2014).

In 2009, BPCF proposed fourteen sustainability indicator targets and were approved by the BPCF council. According to (British Precast, 2011) these targets include;

1. the energy reduction i.e. overall kWh/tonne by 10% ;
2. reduction of production carbon emission by 10%;
3. reduction of waste to landfill i.e. kg/ tonne by 10%;
4. reduction of water main consumption by 5%;
5. reduction of ground water consumption by 5%;
6. increasing the proportion of alternative cement addition (as a % of total cement) to 25%;
7. increasing the proportion of recycled/ secondary aggregates (as a % of total aggregates) to 25%;
8. reduction in reportable injuries per 100, 000 direct employees by 10% per year;
9. increasing the % of production sites covered by EMS (e.g ISO 14001) to 85%;
10. increasing the % of production sites covered by Quality system (e.g ISO 9001) to 85%;
11. reduction in convictions for air and water emissions to zero
12. improving the capture of transport data
13. increasing the % of employees covered by a certified management system (e.g. ISO 9001/ ISO 14001/ OHSAS 18001) to 85%, and;
14. Maintaining the % of relevant production sites that have community liaison activities at 100%.

By 2013, the industry membership has met 13 out of the 14 KPI targets for 2012. This include; energy consumption per tonne reduction by 10%, 25% increase in the use of alternative low carbon cement, waste reduction by 10%, carbon emissions reduction by 10% which is equivalent to 0.14 million tonnes of CO2 saved which is almost 0.5% of the total embodied carbon emission of the UK construction industry (MPA British Precast, 2013:7).

The industry is looking into the future, another set of targets similar to the fourteen mentioned above have been approved by the BPCF Council for the year 2020 with a baseline year of 2012.

2.2.3.1 Responsible sourcing ‘era’

Responsible Sourcing is: *‘demonstrated through an ethos of supply chain management and product stewardship. The scope of Responsible sourcing of materials (RSM) is broad and* *encompasses the social and economic aspects of sustainability as well as environmental'* (Anderson *et al.*, 2009:9) A standards BES:6001 was developed by BRE with input from a range of industries. The precast concrete industry in collaboration with others also developed a guidance document on Responsible Sourcing of Construction Products standard (BES: 6001). The standard demonstrates to stakeholders that products are sourced responsibly; helps improve the overall social and environmental performance and provides an access to schemes such as BREEM and Code for Sustainable Homes (BSI, 2014). The Building Research Establishment (BRE) consulted the construction product sectors; for the framework standard - responsible sourcing of construction products BRE BES6001: 2009 (BRE Global, 2009). A guidance document for interpreting BES 6001 for concrete producers was also developed in collaboration with BRE.

With funding from DEFRA and the support of WRAP and CERAM, in 2013, a Resource Efficiency Action Plan (REAP) for the precast concrete industry was developed which helps to address the entire supply chain (British Precast, 2013). REAP serves as a collaborative mechanism that will see the industry stakeholders (contractors, architects and builders merchants) to address issues related to transport, pallets, and resource efficiency at construction sites.

The precast concrete industry has also been part of the larger UK concrete industry wide sustainability initiatives, which include the concrete industry sustainability strategy targets since 2008. However, the (understandably) scope of these initiatives' coverage does not necessarily ensure that they best meet the needs of, and/or exploits the specific development opportunities that, could be realised within particular parts of the industry.

2.2.4 SUSTAINABILTY ASSESSMENT METHODS OF RELEVANCE TO THE PRECAST CONCRETE INDUSTRY

2.2.4.1 The Green Guide to Specification

The first edition of the Green Guide was published in 1996, now in its fourth edition. "*Green Guide to specification provides designers and specifies easy-to-use guidance on how to make the best environmental choices when selecting construction materials and components*" (Anderson *et al.*, 2009:3). It has more than 1500 specifications used for various building types (BRE, 2014). The Green guide forms part of BREEAM and uses LCA from BRE's

Environmental Profile Methodology 2008; this is examined based on relative environmental impacts of construction materials in six generis building types: Commercial buildings, such as offices; Educational; Healthcare; Retail; Domestic and Industrial (BRE, 2014). The Green Guide 'A+' for best environmental performance to 'E' for the worst. The summary rating is a measure of overall environmental impacts covering the following issues:

- Climate change
- Water extraction
- Mineral resource depletion
- Stratospheric ozone depletion
- Human toxicity
- Ecotoxicity to freshwater
- Nuclear waste

2.2.4.2 Code for Sustainable Homes (CfSH)

In the UK, the CfSH is the national standard developed by the government in close working consultation with Construction Industry Research and Information Association (CIRIA) and Building Research Establishment (BRE). The standard is aimed at guiding the industry to in the designing and construction of sustainable homes. The CfSH awards new homes with ratings from level one to level six, with one being the minimum and six the maximum (DCLG, 2010). The CfSH has nine design categories which are all sustainability related: Energy/CO2; pollution; water; health and well-being; materials; management; surface; water run-off; ecology and waste (DCLG, 2006). Like BREEAM, the CfSH also uses the Green Guide to Specification to consider embodied environmental impacts of various specification options and awards credits for specification which has minimal environmental impacts (Anderson *et al.*, 2009).

Precast concrete manufactures certainly have advantages to gain with these sustainability assessment methods. Specifies (i.e designers, architects, planners, engineers e.t.c) of different building products make use of BREEAM, CfSH and the Green Guide to specification for making a choice on a particular product with regards to its environmental credentials (i.e performance, impacts e.t.c) .

2.2.4.3 Building Research Establishment Environmental Assessment Methodology

In the UK, the Building Research Establishment Environmental Assessment Methodology (BREEAM) is the most widely used environmental assessment method that has a rating system for buildings, with more than 250, 000 building rated (BREEAM, 2014). It sets standards for best practise in the sustainable building design, construction and operation and the entire building environmental performance (BREEAM, 2014). BREEAM addresses environmental and sustainability issues and help different stakeholders (developers, architects, engineers, specifies and building managers) to show the environmental credentials of their buildings to their clients, planners e.t.c (BREEAM, 2014).

The BREEAM Manual (2008) provides a table for the ten categories shown in table 2.2.

Table 2.2 BREEAM 2008 environmental weightings

BREEAM Section	Weighting (%)
Management*	12
Health & Wellbeing*	15
Energy*	19
Transport	8
Water*	6
Materials	12.5
Waste*	7.5
Land Use & Ecology*	10
Pollution	10
Innovation	10

* Sections with mandatory credits

BREEAM awards points or credits in ten different environmental impacts categories (i.e energy, management, health and wellbeing, transport, water consumption, materials, waste, pollution, land use and ecology); the overall number of credits achieved in each environmental impact category is multiplied by an environmental weight factors which is based on relative importance for each category, section scores are added to provide an overall single score (BREEAM, 2011). This is then translated to ratings as follows:

- ✓ Pass
- ✓ Good
- ✓ Very Good
- ✓ Excellent
- ✓ Outstanding

BREEAM uses the Green Guide to Specification to consider embodied environmental impacts of various specification options and awards credits for specification which has minimal environmental impacts (Anderson *et al.*, 2009). It has a global recognition and sound reputation and is widely regarded as one of the best tools for environmental assessment.

2.2.4.4. Environmental Profiles Certification Scheme

According to BRE (2014a), *Environmental Profiles Certification Scheme "provides ongoing independent, third party assessment and certification of materials and products for their environmental performance*." In the UK, the BRE Environmental Profiles Certification Scheme serves as an EPD to which manufacturers can communicate the environmental information and performance of their products (Anderson *et al.*, 2009). Anderson *et al.*, (2009), further explains that the EPD scheme is based on Product Category Rules (PCR) defined in the environmental profile methodology (BRE Global, 2009a), and the Green Guide is used to serve as a platform for manufacturers to demonstrate their performance against other generic products. The scheme also allows product performance claims by the manufacturers and their trade association for typical UK performance.

The BRE Environmental Profiles will certainly be of importance to the precast concrete industry. As these data will serve as good material for reference, improvements and collaboration (for example share of information e.t.c). Also, for the precast concrete manufacturers, a closer look at all the relevant European standards (for example; CEN 350; CEN/ TR 15941; EN 15942; EN 15643-4: 2012; EN 15973; EN 15643-2: 2011; EN 15643-1:2010 etc.) will be very beneficial to the industry.

2.2.5 SUSTAINABILITY MANAGEMENT

Within literature, there seems to be agreement on the key elements of sustainability management. For example, Hopwood *et al.*, (2005) suggested that sustainability is about '*a range of environmental issues with socio-economic issues*' and Carter and Rogers, (2008) made a clear link between environmental, social and economic goals, but believe that many companies implement environmental and social plans or strategies in a fragmented and disconnected way. Burke and Gaughran (2007) suggested that a key step towards sustainability is the attainment of ISO140001 and other standards such as ISO9001 and OHSAS18001. This was confirmed in the precast industry by Holton *et al.,* (2010) who investigated the precast concrete industry's management of sustainability issues. Curkovic and Sroufe (2011:87) maintain that standards like 14001 give '*significant benefits internally and externally in terms of a sustainable supply chain strategy'* and in the right hands can be a tool for sustainability in the supply chain. Critics however point out that it does not ensure a level playing field. This is based on opinions by different critics that despite its perceived benefits, there is a lack of link between environmental performance and ISO14001 (Landon, 2003), registration of stakeholder satisfaction and firms demonstration of compliance are not a major requirement in ISO 14001 (Vastag *et. al.*, 2004 and Curkovic *et. al.*, 2005) and ISO 14001 is viewed by some managers that it focuses too much on documentation and bureaucracy (Curkovic and Sroufe, 2011).

That said, Lozano (2008) and Lozano and Huisingh (2011) warn that the social, economic and environmental aspects of sustainability interact with each other, and should be measured and reported in an inter-linked manner. In the view of Erlandsson and Tillman (2009) relevant, comprehensible and verifiable information is required and necessary in any attempt to mitigate the environmental impacts of a product from production, manufacture and consumption. This has been through Environmental product declarations which this is discussed in section 2.4. The next section 2.3; provides a general overview of product stewardship and its link with sustainable development.

2.2.6 THE CONCEPT OF UK ECOPOINTS

According to Concrete Society (2014), "A UK Ecopoint is a single unit measurement of environmental impact. It is a measure of the total environmental impact of a particular product or process expressed in units (ecopoints). Ecopoints are calculated from LCA data based on environmental impacts in the UK are applicable to the UK. (Concrete Society, 2014).

A more detailed definition of Ecopoints by BRE (2000 and 2014) "is a measure of the overall environmental impact of a particular product or process covering the following environmental impacts; Climate change, fossil fuel depletion, ozone depletion, human toxicity to air, human toxicity to water, waste disposal, water extraction, acid deposition, ecotoxicity, eutrophication, summer smog and minerals extraction".

Eco points where developed to provide a balanced judgement and/or assessment methodology on the relative importance of the different environmental impacts associated with the construction process. For more information on how Eco points where used in the research please go to chapter five.

2.3 AN OVERVIEW OF PRODUCT STEWARDSHIP (PS)

To gain an understanding of product stewardship (PS), an extensive literature review was carried out from which it was clear that there was no single agreed definition; similar to discrepancies found when attempting to characterise other terms such as 'sustainability' or ‘sustainable development’ (Lewis, 2005; Merlot, 1998). A range of definitions of PS is presented in Table 2.3, which clearly show the key concepts that underpin the term. These definitions represent and interpret the understanding, operation and implementation of PS by different global perspectives both in the public and private sectors, multinational organisation, academicians, and primary research in different parts of the world. The subject areas these definitions cover are wide, they include but are not limited to; environmental protection, product life cycle, stakeholder shared responsibility, environmental, health and social impacts, life cycle management, product use ((OECD, 2005; US EPA, 2013: 1; (Pitchell, 2005: 641; PSI, 2010: 1; NWPSC, 2010: 1; PSF, 2010: 1; Bruijn in Visseret al., 2007: 378; Hart, 1997: 71; Hart, 2007: 69; Madu, 2007, p.99; Lewis, 2005, p.50; Lewis, 2010: 196 and PSI:2014:1. It must be noted however, that most of the definitions in table 2.2 clearly focused on environmental, social and health aspects without the mention of economic aspects. However, the works of Hart (1997:73) makes a clear link between PS and economics (i.e revenue growth).

Table 2.3: Selected definitions for PS from literature.

Definition	Reference
"PS is a product-centred approach to environmental protection. It calls on those in the product lifecycle—manufacturers, retailers, users, and disposers — to share responsibility for reducing the environmental impacts of products".	(OECD, 2005; US EPA, 2013: 1).
"PS transfers the responsibility of end-of-life management from the public sector (i.e government and taxpayers) alone to shared responsibility that includes the private sector (manufacturers and purchasers)".	(Pitchell, 2005: 641)
"PS is a principle that directs all participants involved in the life cycle of a product to take shared responsibility for the impacts to human health and the natural environment that result from the production, use, and end-of-life management of the product."	(PSI, 2010: 1).
"PS is an environmental management strategy that means whoever designs, produces, sells, or uses a product takes responsibility for minimizing the product's environmental impact throughout all stages of the products' life cycle, including end of life management".	(NWPSC, 2010: 1).
"PS is a 'cradle to cradle' methodology that helps reduce the environmental impact of manufactured products. Under PS schemes, producers, brand owners, importers, retailers, consumers and other parties accept responsibility for the environmental effects of their products – from the time they are produced until the end of their useful life and disposed".	(PSF, 2010: 1).
"PS is a product-centred approach to environmental management and aims at improving the environmental performance of a product throughout its complete life cycle".	(Bruijn in Visser*et al.*, 2007: 378).
"PS focuses on minimising not only pollution from manufacturing but also all environmental impacts associated with the full life cycle of a product".	(Hart, 1997: 71).
"PS extends beyond organisational boundaries to include the entire product life cycle, from raw material access through production process, to product use and disposal of spent products".	(Hart, 2007: 69).
"The concept of PS requires the manufacturer to take responsibility for its products throughout their lifecycle and to continuously seek methods to improve the environmental quality of the products".	(Madu, 2007, p.99).
"PS is generally used to describe a principle underlying policy approaches to the environmental management of products. It implies increased responsibility by industry for the management of products throughout their life cycle, often with particular reference to disposal or recovery at end-of-life".	(Lewis, 2005, p.50).
"Product centred approach to environmental management"	(Lewis, 2010: 196)
"PS is the act of minimizing health, safety, environmental and social impacts, and maximizing economic benefits of a product and its packaging throughout all lifecycle stages. The producer of the product has the greatest ability to minimize adverse impacts, but other stakeholders, such as suppliers, retailers, and consumers, also play a role. Stewardship can be either voluntary or required by law."	(PSI:2014:1)

PS is relevant in the broader context of sustainability and sustainable development (Nightingale and Donnette, 2002). Brady *et al.*, (1999) describe PS as one of the key tools or management systems used to support sustainable development in industry, inclusion of environmental aspects such as the use and consumption of resources and waste generated from raw material extraction and processing, production of the product, product use and final disposition of products. Hence, PS is generally understood to be a part of environmental management, relating to production (Kreith and Tchobanoglous, 2002).

In keeping with the inter-generational aspect of sustainable development and to avoid being vulnerable in the future, companies are becoming more forward thinking by taking responsibility for their products by practicing PS and through the development of new technologies(i.e. through process or product innovation) (Armstrong and Kotler, 2006). Properly implemented, PS offers the probability of 'revenue growth through product differentiation' (Hart, 1997:73). Nicol and Thompson (2008: 228) thus identify a continuum for this, comprising PS, shared responsibility, shared producer responsibility, producer responsibility and Extended Producer Responsibility (EPR), as illustrated in Figure 2.4.

<---------------------------- **Decreasing producer responsibility** <--------------------------

Product Stewardship	Shared Responsibility	Shared producer Responsibility	Producer Responsibility	Extended Producer Responsibility

-----------------------------> **Increasing producer responsibility** ------------------------->

Figure 2.4: Continuum of producer responsibility for different strategies (Nicol and Thompson, 2008: 228).

Hart (1997) and Hart and Milstein (2003) have developed a sustainability portfolio that shows four dimension of sustainability which include:

1. Pollution prevention;
2. Product stewardship;
3. Clean technology; and,
4. Sustainability vision.

Hart and Milstein are of the view that *Pollution prevention* focuses on what are the waste and emission streams within an organisation's operations. It also looks at what are the cost implications and risks attached to eliminating waste at source or using waste as a useful input for example through recycling.

Product stewardship looks at product design and development as well as the uptake of responsibility through the product's life cycle. These also include how to add economic value to the product or lowering costs and at the same time reducing the products impacts. On Clean technology, Hart and Milstein's views are that environmental performance and the potential to make improvements through the advance of new technology is essential. Finally, the key the *Sustainability vision* as espoused by Hart and Milstein posed a question; does organisational corporate vision provide a pathway solution for social and environmental problems? In their view, the development of new technologies, markets, products and process should consist of all these elements.

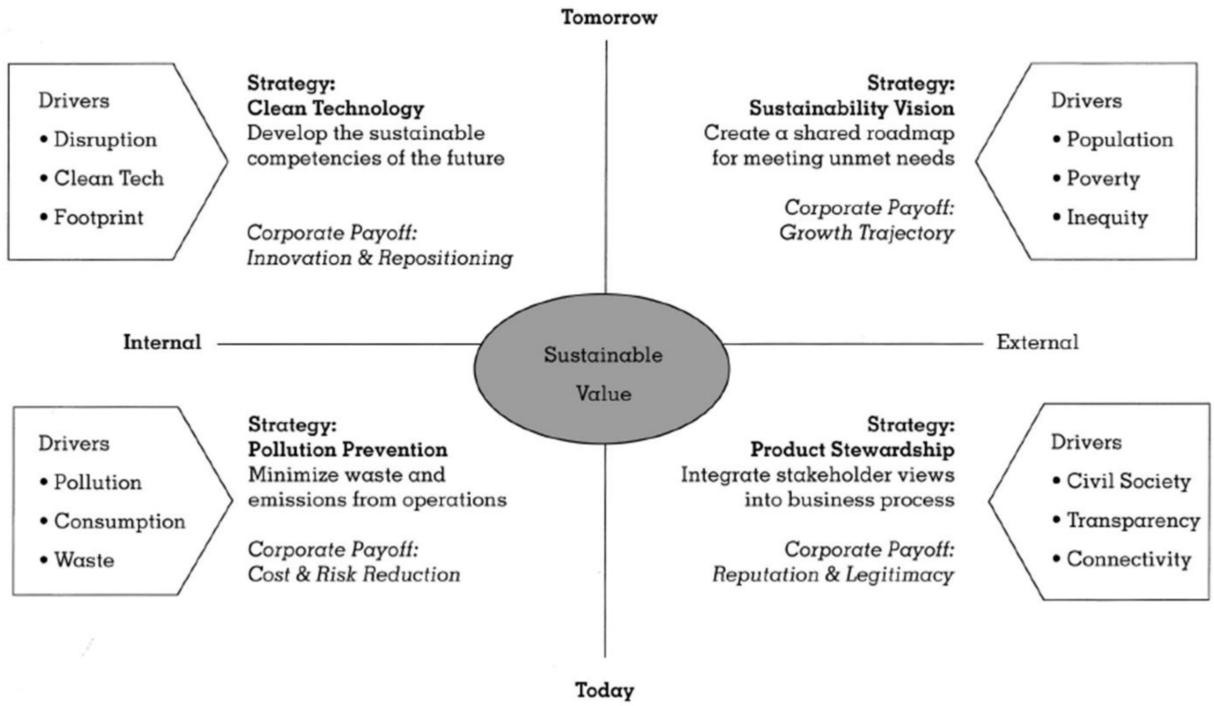

Figure 2.5: Sustainable Value Framework (Hart and Milstein, 2003:60).

Another viewpoint from academic literature also helps in setting the context. The works of Ryding (1998: 665) goes further to identify three key components within PS, as shown in Figure 2.5. This includes:

1. Material efficiency;
2. Environmental and health impact; and,
3. Performance.

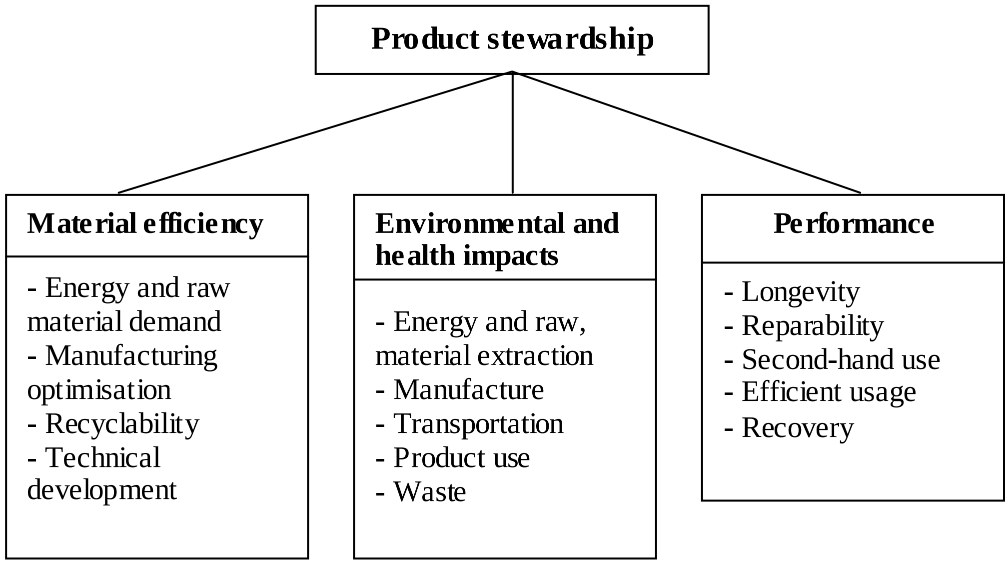

Figure 2.6: Key components of PS (Ryding, 1998: 665)

From another perspective, according to the Global Product Stewardship Council (GPSC, 2014), PS has five key principles which includes;

1. Responsibility,
2. Internalise costs,
3. Incentives for cleaner products and sustainable management practices,
4. Flexible management strategies, and,
5. Roles and relationships.

From all the academic literature studied, there is evidence to suggest that product stewardship consist of multiple key issues which can be broadly categorised into environmental, social and economic.

Based on all of the above, the adopted definition in this research is: 'the taking of responsibility by the precast concrete industry and its stakeholders to mitigate the key environmental, social and economic impacts of their products throughout their life cycle from cradle to cradle'. The next section presents an overview of selected PS schemes in an attempt to unpick the detailed components of the concept.

2.4 OVERVIEW OF SELECTED PS SCHEMES

The concept of PS was introduced in 1972 by the (then) President of Dow Chemical, Ben Branch, to alleviate risks in the use of chemicals (DeSimone and Popoff, 2000; Lipmann, 2000, 2009; Rainey, 2006). According to Lewis (2005), however, its origins are generally attributed to three following separate developments.

1. The Responsible Care initiative by the Canadian and American chemical industry associations.
2. Extended Producer Responsibility (EPR) policies development around Europe; and,
3. The adaptation of PS as EPR in the USA.

Indeed, since its early implementation in the 1970s to date, many industries, governments, multinational corporations and countries have developed and implemented successful PS schemes to reduce environmental and social impacts associated with products and services. A number of PS schemes are still in use by a range of industries, groups, and governments for different products; these include the electric and electronic industries, chemical industries, packing and packaging industries, car industries. A few product groups have also successfully developed and implemented PS schemes, using both voluntary and mandatory frameworks (as discussed later). These have been implemented at five different strategic levels, as shown in Figure 2.7.

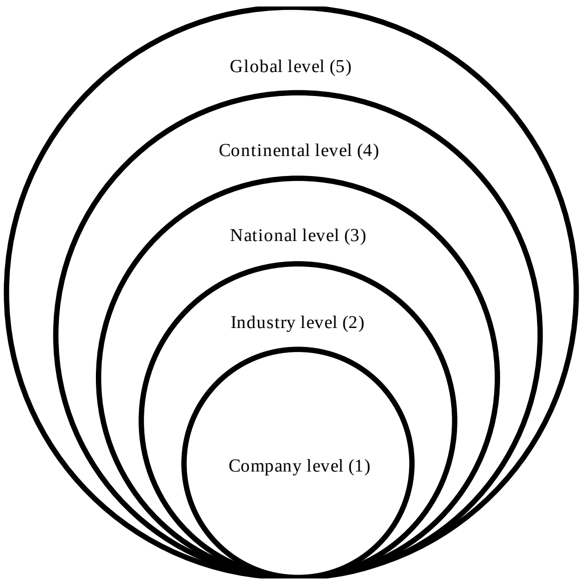

Figure 2.7: Strategic levels of PS scheme implementation (Aliyu *et al.,* 2012).

The top level, which is the *global* level, is concerned with an overall implementation of the scheme throughout the world by an industry, a company or several national governments. For example, the Responsible Care Initiative - a voluntary global initiative of the Chemical industry – has a global outreach to 53 countries and applies to around 90% of global chemical production (Responsible Care, 2010). At *continental* and *national* levels, the OECD developed a guidance manual for national governments on EPR responsibilities regarding pollution control. The Waste Electric and Electronic Equipment (WEEE) Directive 2002/96/EC is an example of a mandatory scheme that has been implemented at four different levels; industry level, continental level, national level and company level. All that said, PS has to be implemented by manufacturers and producers at *company* level, since companies have both the principal ability and responsibility (US EPA, 2010) to make any modification or changes with regards to the environmental, health or social impacts of their products and services. The following sub-sections examine four approaches (from the electric and electronic, chemical, packaging and automobile industries). The comparison and evaluation of these schemes and programmes focuses on identification of stakeholders in each of the schemes, drivers for the implementation of the schemes, the life-cycle environmental and social impacts, mitigation or reduction blueprints or roadmaps adopted by each scheme and the main features of implementation and challenges and prospects for their future. The aim was to extract key lessons from the schemes to inform the UK precast concrete industry about how PS might help in its progress on sustainable development.

2.4.1 ELECTRIC AND ELECTRONIC INDUSTRIES

The Waste Electric and Electronic Equipment (WEEE) - Directive 2002/96/EC of the European Union (EU) is one of the most widely known mandatory regulations that came into force by legislation in 2003. The main objective of its implementation in all countries is to help reduce waste and encourage recycling and reuse. Consumers are responsible to take-back of e-waste free of charge while producers are responsible for providing the facilities to collect, dismantle and recycle or reuse the e-waste (European Commission, 2010). Collection schemes are provided by producers, and consumers are to return their used e-waste to these schemes. The electronic industry in Europe and other parts of the world have implemented PS schemes and Extended Producer Responsibility (EPR) schemes to suit individual countries and regional goals and objectives, which are all centred on waste from obsolete, disused, scrap, faulty or unwanted electronic devices or equipment. These are summarised (by country) in Table 2.4 and (by manufacturer) in Table 2.5.

Table 2.4: Summary of PS schemes for electric and electronic waste in the EU and some selected countries

Country	UK	France	Germany	Austria
Driver	Waste Electric and Electronics Equipment direct (WEEE) 2002/96/EC main underlying driver for implementation across Europe			
Scheme name	The WEEE regulations/ ROHS	WEEE	Electrical and Electronic Appliances Act (ElektroG)	EAG-VO also referred to as "Elektroaltgeräteverordnung" (EAG-VO)
Drivers	Regulatory/ Mandatory			
Year of implementation	2007	2005	2005	2005
Objective of implementation	To minimise the impact of electrical and electronic goods on the environment, by increasing re-use and recycling and reducing the amount of WEEE going to landfill.	Producers will be required to take into consideration product designs that facilitate dismantling and recycling of products.	To avoid electronic waste, increase the re-use, recycling and recovery of waste and to decrease the contents of hazardous substances.	Reuse and recycling of e-waste and the substitution of hazardous substances with safer alternatives.
Product categories	– Large household appliances – Small household appliances – IT & Telecommunications equipment – Consumer equipment – Lighting equipment – Electrical and electronic tools – Toys, leisure and sports equipment – Medical devices – Monitoring and control instruments – Automatic dispensers – Display Equipment – Cooling Appliances containing refrigerants – Gas Discharge Lamps	– Major appliances – Small appliances – Equipment and telecommunications – Consumer equipment – Lighting equipment (except lighting equipment and household incandescent lamps, which do apply – Electrical and electronic tools (except large stationary industrial tools) – Toys, leisure and sport – Medical devices (with the exception of all implanted and infected products) – Instruments of surveillance and control – Vending machines	– Large household appliances (e.g. refrigerators) – Small household appliances (e.g. coffee, machines) – IT and telecommunications equipment (e.g. computers) – Consumer equipment (e.g. radio and TV sets) – Lighting equipment (e.g. fluorescent lamp) – Electrical and electronic tools with the exception of large scale stationary industrial tools – (e.g. drills and saws) – Toys, leisure and sports equipment (e.g. video games) – Medical devices with the exception of all implanted and infected products (e.g. X-ray equipment) – Monitoring and control instruments (e.g. smoke detectors); Automatic dispensers	
Stakeholders	– Producers (any business that manufactures, imports or rebrands electrical and electronic products) – Retailers and Distributors (any business that sells electrical and electronic equipment to end users) – Local authorities – Waste management industry – Exporters and re-processors Business and other non-household users of EEE	– Producers – Distributors – Municipalities – Retailers	- Consumers - Producers - Manufacturers - Retailers and distributors -Public waste management authorities	Producers Distributors Municipalities Retailers Importers

Sources: BIS (2010); Dully *et al.* (2009), Gramatyka *et al.*(2007) and EC (2010).

Table 2.5: Summary of some selected PS schemes in the Electric and Electronic Industry (EEI) by companies

Companies	**Hewlett Packard**	**Motorola**	**Dell**	**IBM**	**Microsoft**	**Sony Corporation**	**Xerox**	**Philips**
Operating revenue/Sales	$200 billion	$30.146 billion	$61.101 billion	$103.63 billion	$58.437 billion	Y7,730.0 billion	$ 17.0billion	€28.0 billion
No. of employees	321, 000	64,000	76,500	398,455	93,000	180,500	55,000	121,000
Scheme name	Product stewardship program	Green Design project	Dell product stewardship	Product stewardship programme	Corporate policy/ statement on product stewardship	Sony's environmental Vision and mid-term Green Management Targets	Asset Recycle Management (ARM)	EcoVision4 environmental program
Driver	Design for environment	Design for environment	Design for environment	Environmental design	Environmental principles	Environmental design	Resource recovery	Product stewardship
Year of implementation	1992	No data found	1991	1991	No data found	1991	1991	1994
Products	Printing, computing, software, services, and information technology (IT) infrastructure.	Mobile Phones, Accessories, Walkie Talkies, Cordless Phones, Home Networking and more.	Desktops, Notebooks, Printers, Scanners, Storage Servers, Televisions, Notebooks, Peripherals	Software, Storage, Personal computers, internet security, server and systems, semi-conductors, printing systems from info print	Software, Computer games consoles.	Audio, Video, Televisions, Information and communications, Semiconductors, Electronic components	Colour printers, copiers, business consulting services, copier and printer supplies	Healthcare, lifestyle and lighting
Objective of implementation	Reduction of environmental impact of products, minimise waste going to landfills and help customers manage products at their end-of-life management.	To develop and implement standards, methods and tools for environmentally conscious product Design.	Reduction and elimination of corrugated, plastic foam, and wood Materials.	Environmental life cycle considerations from product concept through product end-of-life management.	N/A	Waste minimisation, waste management, and consideration of environmental impact when evaluating new products, projects, and operations.	Environmental strategic goal is to become a waste-free company.	Improving energy Efficiency of products and operations.
Product categories	All products	All products	Packaging	Photocopiers, computers	Software, computer gadgets, game consoles	Electronics	Electronics	All products
Stakeholders	Environmental strategies councils, Producer and Users	Producer and Users	Producer and Users	Producer and Users	Producer and Users	Producer and Users	Producer and Users	Producer and Users
Tools used	EPA Smartway, take-back options, including asset recovery, donation, leasing returns, remarketing, refurbishment, trade-in and recycling.	Customised software was developed to help engineers calculate life-cycle environmental impacts and compare different material and processes used to create a product.	Recycling and recovery.	Green Sigma, Take back and recycling programme.	N/A	Shared responsibility take-back systems.	Life Cycle Management, Take-back / Integrated recycling programme.	Life Cycle Approach (LCA)

Sources: Fiksel, J. 2009;Motorolla, 2010; Dell, 2010; Davis, J.B., 1996; IBM, 2010; Microsoft, 2010; HP, 2010; Philips 2010.

2.4.2 CHEMICAL AND PETROCHEMICAL INDUSTRIES

Over the years the global chemical industry has been under increasing pressure because it continues to put 'enormous pressure on air and water resources by their products and processes many of which are highly toxic and resource intensive' (Hart and Milstein, 1999). Governments, industry and stakeholders have developed an international policy framework centred on the product stewardship of chemicals; under the International Council of Chemical Associations (ICCA) a voluntary charter was initiated in the early 1980s (ICCA, 2009) for national associations to work together in the improvement of health, safety and environmental performance and to communicate to all their stakeholders regarding process and product innovation. It has nine key principles and is centred on waste minimisation and resource efficiency, objective and open performance reporting on achievements and shortcomings, joint collaboration with stakeholders in regulation implementation and providing support to chemical managers in the effective chemical management (Responsible Care, 2010).The progress achieved was as a result of the implementation of the Responsible Care Global Charter (RCGC) and the Global Product Strategy (GPS) as part of United Nations/ Strategic Approach to International Chemicals Management (SAICM) (ICCA, 2010). The main tool used for measuring progress is an annual questionnaire based on the Responsible Care Charter, including a scale of three status levels used to measure performance.

Table 2.6 presents a summary of selected PS schemes implemented in the chemical and petrochemical industry, by company.

Table 2.6: Summary of selected PS schemes in the chemical and petrochemical industry by companies.

Company	Dow Chemical	DuPont	BASF	Shell Chemicals
Operating revenue/ Annual sales	$54.0 billion	$30.0 billion	$70. 0 billion	$405 million
Number of employees	46, 000	60,000	95,000	6,000
Scheme name	Product stewardship programme	Sustainable growth	Product Stewardship system	Product Stewardship programme
Driver	Design for environment and eco-efficiency	Sustainable growth and eco-efficiency	Eco-efficiency	Responsible chemistry
Year of implementation	1992	1990's	1991	No data found
Products and services	Printing, computing, software, services, and information technology (IT) infrastructure.	Agriculture, Building & Construction, Electronics, Energy & Utilities, Health Care & Medical, Manufacturing, Packaging & Graphic Arts, Plastics, Safety & Protection, Transportation.	Chemicals, plastics, paints, catalysts, coatings, electronics, pharmaceuticals, agro-chemicals.	Alpha olefins/detergent alcohols, Aromatics, Ethylene oxide/glycols, Lower olefins, Propylene oxide and derivatives, Solvents, Styrene, monomer/others.
Objective of implementation	Reduction of environmental impact of products, minimise waste going to landfills and help customers manage products at their end-of-life management.	Increasing shareholder value added while decreasing raw material and energy inputs and reducing emissions. Linking sustainability with business prosperity through Market-Facing Goals and Footprint Goals. Stretch goals like Zero waste, Zero incidences.	Developing and managing a world-class environmental sustainability management of products, processes and tools.	Ensuring that all HSE aspects of Shell's product are responsibly and ethically managed at every stage of the product's life cycle.
Product categories	All products	Building insulation materials, lightweight automotive plastics, synthetic polymers, etc.	Over 100 products e.g building materials, automotive coatings, plastics , etc.	Chemicals
Stakeholders	Dow Chemical staff, suppliers, retailers, wholesalers	DuPont staff, suppliers, retailers, wholesalers	BASF employees, consumers, local community, international community and future generation	Shell staff, hauliers, customers
Tools used	Product and process innovation, e.g. polyethylene from sugar cane, innovative technologies for Agro chemicals e.g Green insecticide Spinetoram and Sentricon for termites.	Market-facing goals and Footprint Goals. Developed a water-based automotive paint system.	Life-cycle carbon balance, SEE balance tool (Socio Eco-efficiency Analysis).	Product and process innovation, hazard communication systems, training to customers.

Sources: BASF (2010); Dow Chemical (2010); DuPont (2010); Fiskel (2009) and Shell Chemical (2010).

2.4.3 AUTOMOTIVE INDUSTRIES

According to the European Commission (EC) (EC, 2010a) in the EU annually, vehicles generate in the range of eight to nine million tonnes of waste. In 2008, the world automotive industries manufactured a total of over 70 million cars and commercial vehicles (International Organization of Motor Vehicle Manufacturers - OICA, 2010). Road transportation globally is responsible for 16% of man-made emissions (from cars, trucks and buses), 20% in the EU and 22% in 2006 for the UK (DEFRA, 2008). The issue of waste and emissions as such have become a major source of environmental and social impacts for the automotive industry and their various stakeholders. To address these problems, the End-of-Life of Vehicles ELV's Directive (2000/53/EC) was implemented in the EU automotive industry in 2000 to set quantifiable targets for the reuse, recycling and recovery of vehicles and their components. It also helps in encouraging the manufacturers of vehicles to consider recyclability. That said, some PS approaches pre-date the ELV directive, such as Toyota's Earth Charter and Global 21 Project, introduced in 1991 (Toyota, 2010).Table 2.7 summarises selected PS schemes in the automotive industry by company.

Table 2.7: Summary of selected PS schemes in the automotive industry by companies.

Company	**GM Motors**	**Toyota**	**Daimler AG (Mercedes Benz)**	**Caterpillar**
Operating revenue/ Sales	$148.979 billion	Yen7,567,000	€95.9 billion	$51.324 billion
Number of employees	204,000	320,808	270,000	112,887
Scheme name	GM's Advanced Propulsion Technology Strategy (GMAPTS)	Toyota Earth Charter and Global 21 Project	Blue-efficiency	Sustainability strategy
Driver	Sustainability	Environmental management	Energy efficiency	Sustainable development
Year of implementation	Data not available	1992	Data not available	2006
Products	Automobile and alternative fuel technologies	Automobile and alternative fuel technologies	Automobile	All products
Objective of implementation	Establishing sustainability through diversifying other sources of energy and reduction of GHG emissions.	Effective environmental management and improvement.	To achieve lower energy emissions ar minimum fuel consumption.	To achieve Caterpillar enterprise goals by 2020 for operations, products, services, and solutions.
Product categories	Gas engines, diesel engines, cars	Cars, fuel efficiency and hybrids systems, fuel cell vehicles	Cars and trucks	Heavy vehicles and trucks
Stakeholders	GM staff	Customers, employees, business partners, shareholders, global society/ local communities.	Staff and customers	Staff, Customers, Stakeholders
Tools used	Product and Process innovation - GMAPTS	Global Vision 2010, Toyota Earth Charter, Zeronize Maximize	Product and process innovation	Product and process innovation

Sources: Fiskel (2009), Toyota (2010); Diamler (2010) and Caterpillar (2010).

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2.4.4 PACKAGING INDUSTRIES

According to the European Commission (EC, 2010b), in the early 1980s the European community introduced measures that aimed to help in the strengthening of the management of packaging. However, some EU member states introduced waste management measures on packaging aimed at the reduction of environmental impacts. In 1992, Directive 94/62/EC was adopted by the EC to help in the harmonisation of different measures adopted by national government to help in the prevention and reduction of the impacts associated with packaging and packaging waste to the environment with clear provisions specified for prevention of waste from packaging, re-use of packaging and recovery and recycling of waste associated with packaging (EC, 2010b). In the UK, the Directive was implemented through "Producer Responsibility Obligations (Packaging Waste) Regulations 2007" (BERR, 2010). A summary of PS for Packaging industries in the EU and selected countries is presented in Table 2.8. It highlights implementation in two countries - the UK and Germany, as well as throughout the EU.

Table: 2.8: Summary of PS schemes for Packaging industries in the EU and selected countries.

Country	UK	Germany	EU
Industry	Packaging industry		
Scheme name	Producer Responsibility Obligations (Packaging Waste) Regulations 2007	The German Ordinance on the avoidance and Recovery of Packaging Waste	Directive 94/62/EC
Scheme type	Mandatory/ regulatory		
Drivers	The Packaging Directive	N/A	Waste reduction and recycling
Year of implementation	2007	1991	1994
Objective of implementation	Is aimed at packaging waste material minimisation and the promotion of reuse, recycle and energy recovery of packaging	To prevent and reduce the impacts associated with packaging waste to the environment	To prevent and reduce the impacts associated with packaging waste to the environment
Product categories	packaging	Transport packaging, secondary packaging and sales packaging	All packaging and packaging waste
Stakeholders	Importers, manufacturers, convertors, sellers, service providers, fillers and Businesses that handle 50 tonnes of packaging per annum and has a turnover of more than £2 million per annum	Manufacturers and distributors (i.e. retailers)	Manufacturers, distributors, importers
Tools used	Take-back systems, recycling and reuse	Take-back systems, recycling and reuse	Take-back systems, recycling and reuse
Recycling mechanism	Individual route or through registered compliance schemes	Duales System Deustschland (DSD)/ Green Dot, arranges the collection, transportation and recycling marked with its logo	Based on national arrangements and agreements

Sources: BERR (2010), EC (2010), Palmer and Walls (2002).

2.5 STRATEGISING FOR PS

Within the literature, there appear to be few critics of PS. Of these, Nicol and Thompson (cited in Thorpe *et al.*, 2004:21) argue that PS programmes are a 'step in the wrong direction because they will not lead to better and safer product design nor will they lead to the phase out of hazardous chemicals in the product'. This view, however, appears to receive little support from the various industries that have implemented PS schemes and principles. While there are a range of approaches and levels of implementation that companies, industries and regions have used to adopt PS, there are some general consistencies in the drivers, scope and intended outcomes (as shown in the analysis of selected schemes). However, the same cannot be said for the issue of mandatory versus voluntary PS approaches; this does appear to divide opinion somewhat, and is discussed next.

2.5.1. MANDATORY PS APPROACHES

The mandatory PS approaches implemented in three of the four industries reviewed have a commonality in purpose, which is a legislative or regulatory requirement for all the stakeholders involved in the product's lifecycle (with the emphasis in this case on end-of-life) to take responsibility (either financially, physically or both) for taking back (user responsibility) and recycling (manufacturers' responsibility). The main goal of the mandatory approaches was to reduce and prevent waste generation by encouraging recycling and reuse. All four mandatory approaches are directives of the European Commission implemented by the 25 member states and transposed into law at different times in the respective EU countries. These are:

1. The European Commission Directive on Waste Electrical & Electronic Equipment (2002/96/EC).
2. The European Commission (EC) Directive on End of Life Vehicles ELV's (2000/53/EC).
3. The European Commission Packing and Packaging Directive (94/62/EC).
4. The European Commission Directive 2002/95/EC RoHs.

The common features shared by the directives are the goal- and target-setting for waste reduction through reuse, recycling and recovery; sharing responsibility between stakeholders involved in the products' end-of-life, and restricting use of hazardous components and parts. However, the use of these legislations has been criticised for its poor track record in stopping the decline in quality of Europe's environment. Rather, environmental economists are of the view that legislation should be supplemented with, or replaced by, New Environmental Policy Instruments (NEPIs), which will include voluntary agreements, eco-taxes and environmental charges (Bailey, 2003).

2.5.2 VOLUNTARY PS APPROACHES

Voluntary approaches and agreements have been identified as key mechanisms that drive effective environmental policy partnership between government and the industry (Bailey, 2003). Palmer and Wells (2002) argue that although voluntary programmes have a positive effect that leads to environmental improvements without mandatory regulation, the major problem with such agreements include: companies and industries can opt out at any time; the schemes can be short-lived; and they may overlap. However, analysis and evaluation of selected schemes as carried out in Section 2.4 (particularly in Table 2.3 – 2.7) show clear evidence of environmental and economic improvements (This is evident at the company level of implementation), where there is evidence of continuous implementation, review of objective and target setting.

Some of the voluntary PS schemes showed a clear intention by all the industries and companies involved to partner with other stakeholders to take voluntary responsibility to mitigate the negative environmental and social impacts to the environment, for example:

- the chemical industry (under the ICCA) voluntarily developed a Product Stewardship and Global Product Strategy (ICCA, 2008);
- various governments under the umbrella of the OECD developed a guidance manual for governments on Extended Producer Responsibility (EPR) (OECD, 2001); and,
- resource and productivity improvements in DuPont enabled the company to save almost $400 million (WBCSD, 2006:d3).

Other individual companies such as HP, DuPont, Dow Chemical, Alcan and BASF have implemented voluntary PS schemes by identifying a set of key issues, focal points and areas and setting short-, medium- and long-term targets. Most, however, also recognised the need to develop or create innovation through product innovation and process innovation in product supply chains. New and Westbrook (2004:244) suggested that this is a key step which includes moving from being reactive to proactive within supply chains comprises; pollution control, pollution prevention, product stewardship and sustainable development (as shown in Figure 2.8). Yet this level of environmental orientation requires a strong partnership amongst all relevant stakeholders within the supply chain.

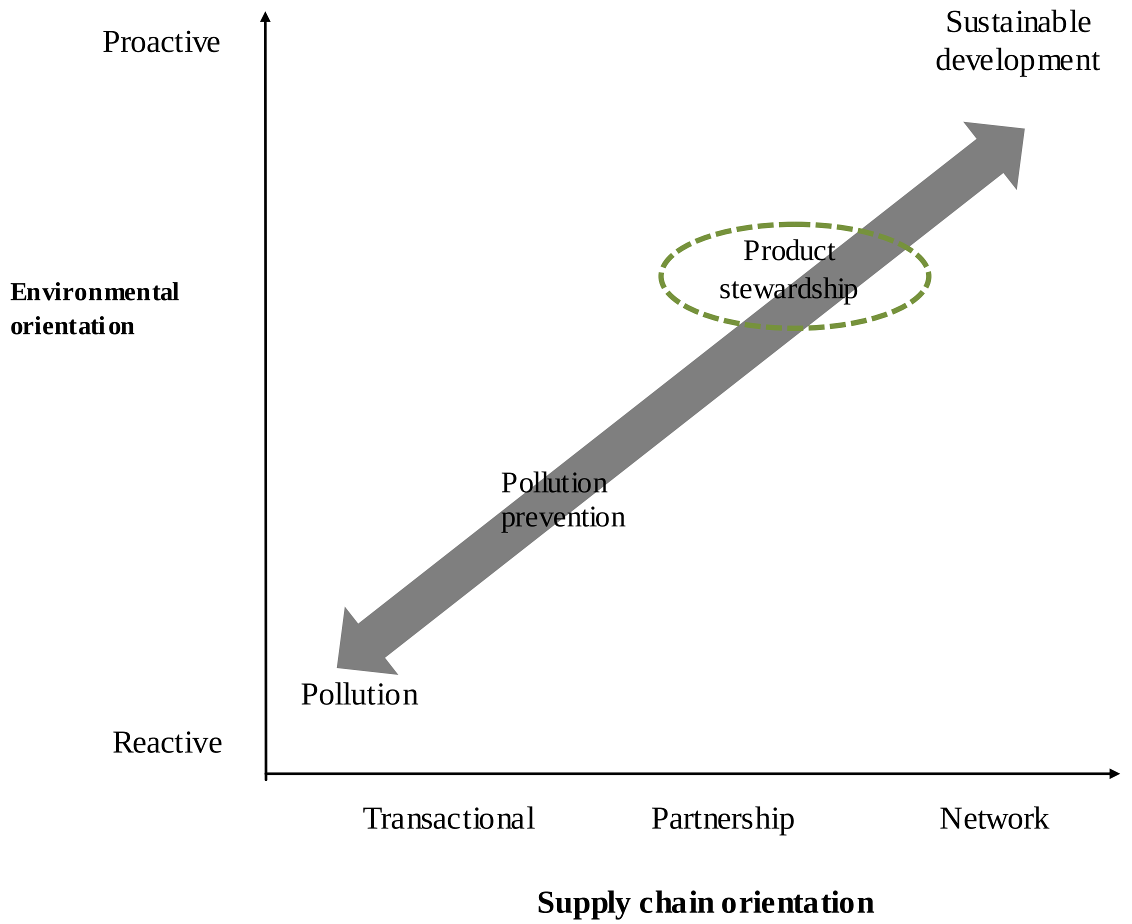


Figure 2.8: Building capabilities toward sustainability (New and Westbrook (2004: 244).

New and Westbrook (2004:244) suggested that supply chain, environmental orientation, and the resulting green supply chain practices in an organisation can be linked in a basic structure as shown in figure 2.8. They opined that environmental and supply chain practices must be viewed to be mutually supportive. They also propose that the progressive capabilities of organisation can advanced up the continuum from the lower transactional supply chain orientation/ reactive to higher up network sustainable development/ proactive. In their view, there is an opportunity to test these relationships.

2.6. ENVIRONMENTAL PRODUCT DECLARATIONS (EPD)

The UK precast concrete industry understands sustainability. This is evident through its sustainability strategy. However, the Construction Product Regulations (CPR) which came into effect in the UK on the 1st July, 2013 mandates that construction products placed in the market must provide information that is reliable and accurate with regards to their performance (EU, 2014). According to the European Commission (EC) (2014), this is achieved through a harmonised, standardised and uniform assessment method of the construction products performances that uses a "common language"; this is applied by:

- construction products manufacturers (when declaring their products performance);
- the authorities of all EU member states (when specifying requirements), and by;
- their users (architects, constructors, engineers e.t.c) when making a product selection/ choice for use in construction works.

This necessity served as one of the basis for the inclusion of environmental product declarations (EPD) as a platform for embedding product stewardship in the precast concrete industry. EPDs serve as specific means of communicating principally environmental information through the life-cycle lens. EPD have an established presence within a range of product manufacturing paradigms across Europe and are of direct relevance to the precast concrete industry, because the wider UK construction products industry is starting to adopt this approach (principally in response to there being points for so doing in schemes like BREEAM) (Anderson *et al.*, 2009; Ingwersen and Stevenson, 2012). EPD have been developed by different organisations and countries like the UK, Sweden, France, Norway, Germany, Italy, US, Switzerland and Australia among other countries (Anderson and Thornback, 2012; Envirodec, 2012; Ingwersen and Stevenson, 2012; Manzini *et al.*, 2006). Product manufacturers are aware of stakeholders' increasing demands and pressure regarding the need to declare, communicate and transmit the environmental credentials and information of products and services. Pressure on companies comes from new regulations and new requirements (Fet *et al.*, 2009). According to Manzini *et al.*, (2006), one of the most effective and innovative ways to achieve this is through the use of EPD, the key objective of which is the systematic communication of environmental information of a product, good or service that is reliable and accurate such that it encourages the need for and supply of, products and service with less environmental stress. According to Skaar *et al.*, (2011), the primary purpose of EPD is to:

> *"enable comparisons between products or services fulfilling identical functions. The comparisons are based on life cycle assessments (LCA) performed on the products and services according to a set of Product Category Rules (PCR) and the ISO14040 series"*.

ISO14025 (2010) states that an environmental declaration is a claim which indicates the environmental aspect of a product or service which consists of quantified environmental data using pre-set parameters which are based on ISO 14040 and/or including, where necessary, any additional quantitative and qualitative information. According to ISO 21930 (2007), "*EPD are based on LCA, LCI and/or information modules. Relevant environmental aspects that have not been covered by LCA are addressed as additional environmental information*". EPDs are increasingly being considered by organisations to transmit vital environmental information about the quality of their products and services (Manzini *et al.*, 2006). They provide companies with a cradle-to-grave approach that facilitates product stewardship throughout the value chain of the product (Kylakorpi *et al.*, 2007). This can be attributed to the need for more credible, comparable, reliable and verified information by concerned supply chain stakeholders within and in some cases outside the supply chain (Erlandsson and Tillman, 2009; Fava *et al.*, 2011; Ingwersen and Stevenson, 2012). These stakeholders can vary from upstream and downstream along the supply chain. Different countries, organisations, companies and industries have developed or are developing EPD, as shown in Table 2.9.

Table 2.9: Comparison of environmental product declaration (EPD) of selected countries

Country	Standardisation body	Programme name	Founded by	Year	Developed areas of PCRs
UK	British Research Establishment (BRE) Global	BRE Environmental Profiles Certification scheme	BRE	2001	Construction products
France	Energy management (ADEME) and the French Standardisation body - Association Francaise de Normalisation (AFNOR)	Display of environmental characteristics of consumer products	National legislation (*le Grenelle de l'Environnement*)	2010	Food, Cleaning products, Personal products, Clothing, Furniture, Cookware, Office products.
Sweden	International EPD Consortium	International EPD system	Swedish Environmental Ministry	-	Agriculture, Forestry and fishery products, Ores and minerals, Energy and water, Food and beverages, Textile and furniture, Wood and paper, Rubber, Plastics, Glass and Chemicals, Metals, Machinery and appliances, Transport equipment and services, Services, Construction goods and services
Japan	Japan Environmental Management Association for Industry (JEMAI)	Ecoleaf and Carbon Footprint of Products	Japan Ministry of Economy, Trade and Industry (MEIT)	2002	Electronics, Office Machines, Utilities, Durable home goods and services

Sources: BRE (2013); Climatedec (2012); Ingwersen and Stevenson (2012); JEMAI (2012).

From a critical perspective, Glass (2012) explains that EPD "do not cover the three pillars of sustainability and so on their own do not constitute a fulsome sustainability assessment of a construction product". Steen *et al.,* (2008) are of the opinion that EPDs are difficult to understand for professional purchasers and sales people. However, some environmental claims can be falsely made in Type 1 EPD without the agreed set-down rules to show transparency and provide correct measurement and reporting (Ingwersen and Stevenson, 2012).

2.7 THE AIM OF EPD

According to (BSI, 2014), "*EPD communicates verifiable, accurate, non-misleading environmental information for products and their applications, thereby supporting scientifically based, fair choices and stimulating the potential for market-driven continuous environmental improvement."* The aim of EPDs is also to allow comparison of similar products to be made and the communication of the results gave rise to the development of EPD based on conducted LCA according to ISO14025:2010. Life-cycle Assessments (LCAs) and Life-Cycle Inventories (LCIs) are developed and used to show the hot spots and cold spots in the entire product's life cycle. In the context of this research, 'Hot spots' are areas within the product's life cycle that have high negative environmental impacts for example; high water usage, waste, high cement use, hazardous waste. 'Cold spots' are areas within the product's life cycle that have less adverse impacts for example; water use for personal consumption, green energy source (i.e solar, wind) .

EPDs are therefore developed according to ISO14025:2010. BS EN 15804:2012+A1:2013. BSI (2014) describes the different approaches to EPD with respect to the life-cycle stages and building assessment information. According to BS EN 15804:2012+A1:2013, *Cradle-to-gate* is a life cycle stage that includes product stages from raw material supply (A1) i.e (extraction and processing, processing of secondary material input (e.g. recycling processes), transport to manufacturer (A2), manufacturing (A3). While *Cradle-to-grave is the "*the product stage, installation into the building, use and maintenance, replacements, demolition, waste processing for re-use, recovery, recycling and disposal, and disposal". BSI (2014). Verghese *et al.,* (2012) gave the following definitions for; ***Cradle-to-gate*****:** "means LCA has incorporated all the processes require to extract and transform materials from the environment and deliver a product to the factory or retail outlet gate". ***Gate-to-gate:*** "term usually signifies that only an intermediate portion of the life cycle has been considered". ***Cradle-to-grave:*** "usually infers that the entire product life cycle has been considered".

2.7.1 RECENT DEVELOPMENTS ON EPD IN THE CONCRETE INDUSTRY

While there are evolving debates within the standards landscape, EPDs are gaining ground as a mechanism to consistently collect and present environmental data, so are of relevance to the management of sustainability within the industry. At present, the Mineral Product Association has developed an EPD for cement (See appendix I for the LCA information and H for the stages used for the EPD), but before 2014 no construction product industries possess a sector-wide understanding or agreed approach on EPDs in accordance with the industry standard, BS EN 15804 (2012) which has now been superseded by BS EN 15804:2012+A1:2013(BSI, 2014), with these interesting developments there seems to be a better understanding of EPD and its importance to industry and its stakeholders. This presents a very strong case and a significant scope to explore this in the precast industry.

2.7.2 EXAMPLE OF EPD IN THE UK CONCRETE INDUSTRY

A typical example of an EPD closely related to the precast concrete industry is the first UK Average Portland Cement EPD published in February, 2014 by the Mineral Products Association (MPA) UK (See Appendix I page 261) which was verified and approved by the Institute for Construction and Environment (IBU) i.e Institut Bauen und Umwelt e.V.Germany (MPA, 2014 and IBU, 2014). The declared product / declared unit were UK average factory made Portland cement per 1 tonne. The EPD provides an average covering all cement and clinker manufacturing sites and MPA cement member sites in Northern Ireland. The EPD was created with a validity period of five years (05/02/2014 to 04/02/2019) and was based on the average UK Portland Cement EPD data collected in 2011. All the major UK Cement manufacturing companies (CEMEX, Hanson UK, Lafarge Tarmac and Hope, UK) provided data from their sites across UK. Appendix H (page 260) shows the five stage process used by IBU Germany for the development of the EPD which is in conformity with ISO 14025 and EN 15804.

2.7.3 HOW EPD's FIT WITHIN A PS SCHEME

PS as explained earlier is the taking of responsibility by all stakeholders within the precast concrete industry to mitigate the environmental, social and economic impacts of their products/ services from cardle to cradle. As a starter, the industry will benefit in communicating its environmental information which is non-misleading, credible, accurate, reliable and verifiable through EPD's. This will provide the general public and all interested parties and stakeholder showcase their environmental credentials of precast concrete products/ services. Comparison can also be made with products that perform similar or same function within the construction industry such as; wood, steel or glass etc.

EPD's can fit very well in a PS scheme for the precast concrete industry. It will provide the opportunity to embed the environmental information of precast concrete products/ service into the environmental impacts mitigation component of PS.

2.8 INDUSTRY RESEARCH SPACE

The review of state-of-the art academic literature, existing standards, schemes and industry reports, internet searches have clearly have influenced the direction and decisions taken during the course of the EngD research. The specific areas include:

- Sustainability and sustainable construction literature review such as Government and industry reports such as; the BERR (2008 and 2009), Optimat, 2008, British Precast's sustainability programme and series of initiatives; BIS, 2012 and 2013; the relevant standards such as; BS EN 15804 (2012), BS EN 15804:2012+A1:2013(BSI, 2014), ISO 14025, ISO 14024 and other related sustainability literature.
- Product stewardship and Life cycle management; and,
- Environmental Product Declarations.

2.9 GAP ANALYSIS

The UK precast concrete industry is without doubt an integral part of any serious commitment to achieving sustainable construction in the UK concrete and construction industry. The key issues highlighted in the review of existing literature have clearly suggested that there is a continuing discourse and dissections around sustainable construction within the industry. This suggests that sustainability is now firmly underway within the field and in particular evident in addressing the needs of the UK precast concrete industry. Remarkable successes have been recorded in terms of advancing the course of sustainable construction within the UK concrete and the construction industry, but more work needs to be done in terms of:

- The issues of LCA for all precast concrete products could potential be an area for research due to the fact that LCA. This issues include; cost, understanding LCA results and time consuming nature);
- Devising a holistic product stewardship/ life cycle management strategy for the industry;
- EPD understanding, development and implementation;
- Management and apportioning of stakeholder responsibilities upstream and downstream the supply chain; most especially the issue of inherited impacts from cement.

2.10 SUMMARY AND CONCLUSIONS

This chapter on related work has provided a general overview of the key issues related to the primary subject area of PS within the context of sustainability, sustainable construction and their application within the construction and concrete industries and EPD. The review has focused on existing academic and industry literature, but also drawn upon examples of PS schemes that have been implemented in companies and countries from four other industry sectors. The chapter also discusses EPD and their importance in communicating reliable and verifiable environmental information of products. This has provided the pertinent industrial background and underpinning academic studies which are necessary to understand the research undertaken, including coverage of the evolving position on EPD and its development. The next chapter focuses on the research methods employed.

3. RESEARCH METHODS

3.1 INTRODUCTION

This chapter describes the research methods adopted in carrying out the EngD research. The goal of the chapter is to provide a review of different research methods adopted by the researcher; mixed methods – quantitative and qualitative. The research methods selected and applied in this EngD are then further discussed.

3.2 OVERVIEW OF THE RESEARCH APPROACH

This section attempts to explain the approach taken, in the context of business and management research.

3.2.1 RESEARCH WITHIN THE BUSINESS AND MANAGEMENT FIELD

Walliman (2011), Maylor and Blackmon (2005) and Maxim (1999) variously define research methods as the tools and techniques used in the process of research. Jankowicz (2005: 220) describes research methods as the '*systematic and orderly approach taken towards the collection and analysis of data so that information can be obtained from those data'*. Research methods are tools used to collect data, whereas methodologies are comprehensive designs, philosophies or frameworks used in investigations (Lapan *et al.*, 2011; Easterby-Smith *et al.*, 2008; Dawson, 2002). Remenyi *et al.*, (1998) define research methodology as '*the procedural framework within which the research is conducted*' and through this; the way in which problems are approached can be applied to a research programme and process. Yet they also note that it can be very difficult to pinpoint a specific research methodology, particularly in the business and management research field, where the research domain is evolving continuously. Blumberg *et al.*, (2005) define business research as '*a systematic inquiry whose objective is to provide the information that will allow managerial problems to be solved*'. Business research also deals with certain aspects of human behavior such as decision making, leadership and social institutions (Thomas, 2003). Indeed, Bryman and Bell (2007) and Saunders *et al.*, (2007) contend that business and management research not only provides findings to help advance knowledge and understanding, but also to solve practical managerial problems.

3.2.2 RESEARCH DESIGN AND PLANNING

Gill and Johnson (2010) identify seven key research phases, as shown in Figure 3.1.

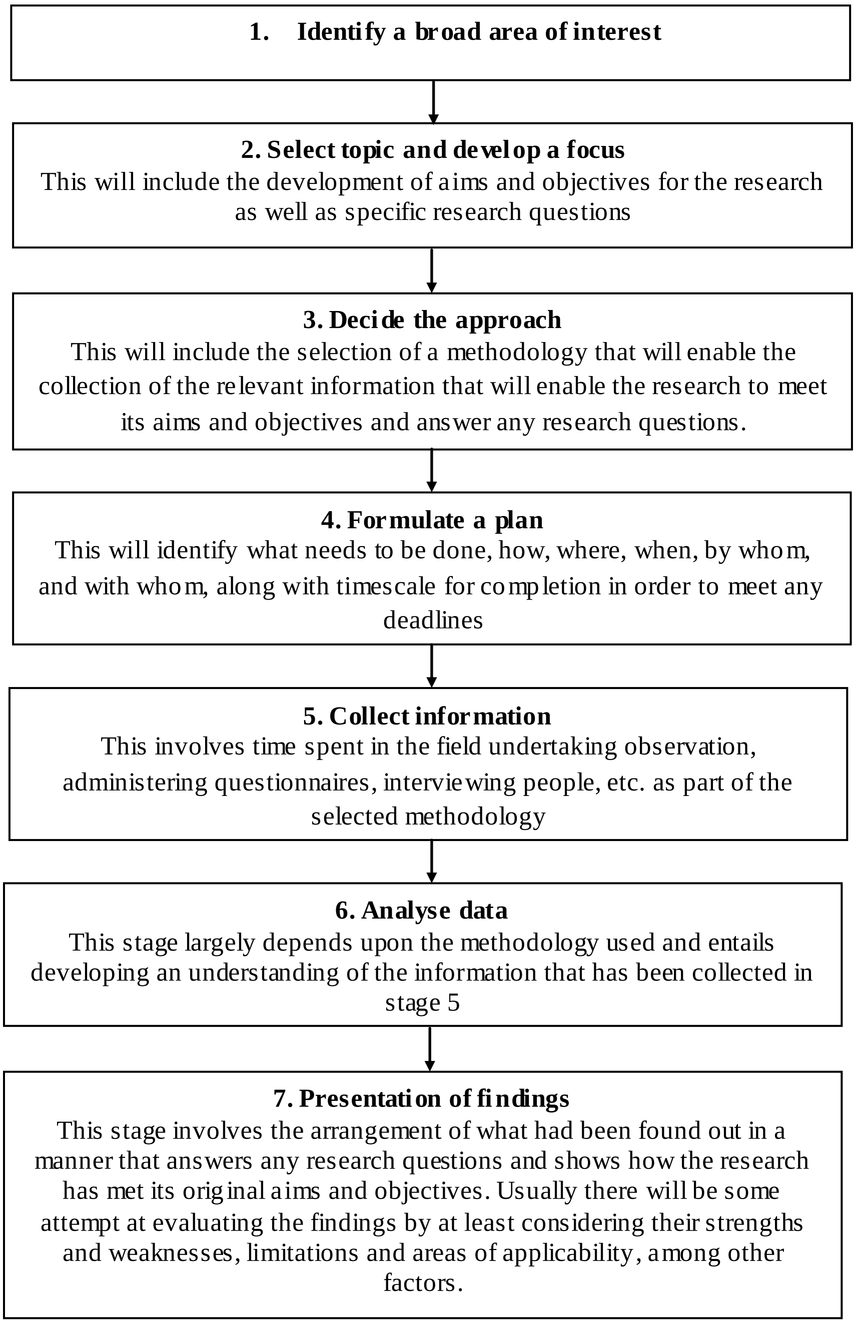


Figure 3.1: The research sequence (Gill and Johnson, 2010:9).

For the purpose of the research, the broad area is *PS and Sustainability*. The topic is PS as a novel sustainability pathway for the UK in the precast concrete industry. The approach and plan are shown in Table 1.1. An overview of approaches/research methods used (interviews, focus group, desktop research, archival analysis and an industry-wide survey) are explained in this chapter, and the results are presented in Chapter Four.

3.3 OVERVIEW OF RESEARCH METHODS

According to Creswell (2007), there are three major approaches to research - qualitative research, quantitative research and mixed methods. But more pragmatically, Yin (1994) suggested there are five major research strategies, as shown in Table 3.1.

Table 3.1 Relevant situations for different research strategies (Yin, 1994: 6 and 2008:8).

Research strategy	Form of Research Question	Requires Control Over Behavioural Events?	Focuses on Contemporary Events?
Experiment	How, why	Yes	Yes
Survey	Who, what, where, how many, how much	No	Yes
Archival analysis	Who, what, where, how many, how much?	No	Yes / No
History	How, why?	No	No
Case study	How, why?	No	Yes

Yin (1994) suggested three conditions when to use each of the five methods in table 3.1. These conditions include:

a. the kind of research question posed;
b. investigators level of control over behavioural events; and,
c. the level of emphasis place on contemporary events as opposed to historical.

In each case, the research question determines what type of research strategy or method to be used. Yin (2008) explains that for example; if the research questions ask the question how? and/or why?, then experiments should be used. Though, there is a potential to be critical of Yin's (1994) work, within literature, the work of Yin (1994) was given credence as Bryaman and Bell (2003) also suggested five research approaches which include; experimental, case study, comparative, cross-sectional and longitudinal. As such, some of these research approaches that can be used to achieve the research objectives were used appropriately and accordingly. A summary of which are as follows:

Objective one was primarily the first stage in the research. A state-of-the art desktop review of academic, industry and government literature was conducted. Literature review was selected as the first and best research method for this task because it has been identified as the Best method to provide a general understanding of the field, find out new or related work and it can help to position my research on the "academic map of knowledge creation" (Ridley, 2012). Archival analysis was employed and key historical perspectives of the industry and its sustainability journey were researched and a longitudinal approach to text related to industry was carried out showing chronology. This served as a 'facts finding' research exercise to understand the main subject domains; the precast concrete industry, the field of sustainability, sustainable construction and their link to the precast concrete industry. Further to this, field surveys (observational site visits) were conducted to understanding and experience the typical precast concrete manufacturing plants, factories and sites. All these were qualitative in nature.

Objective two adopted survey method. Questionnaire survey was conducted with 16 precast concrete member companies which were invited through Email and the Sustainability and Environment Committee of British Precast to take part in the survey. The survey was aimed at exploring the potentials, possible characteristics and implications of implementing PS in the UK precast concrete industry. 12 companies responded and took part in the survey; they represent more than 50 percent of precast concrete production manufacturing in the UK in 2011. After the questionnaire survey, interviews were further conducted to probe the answered questions and gain a in depth understanding of the issues as discussed in chapter four and appendix c ; paper 3.

Objective three focused on the analysis and synthesis of the industry KPI data from 2006 – 2012. A cross -sectional research approach was used. Cross-sectional reash was used because the KPI data analysed and synthesised can best be interpreted since the KPI data is quantitative based and is collected annually. Bajpai (2011) describes cross-sectional – research as the collection of data from a sample at once at a point of time. This provided the basis for identifying trends and key areas of importance to the sustainability management of the industry.

Objective four was achieved through literature review, interviews and a focus group. These series of research methods were employed to first understand what EPD are and how are they of importance to the precast concrete industry. The interviews were chosen to further go into depth and discuss key issues related to recent development and future prospects of EPD and its impact on the precast concrete industry.

As a result of an analysis of these and other research method texts (e.g. Maxim, 1998; Goddard and Melville, 2004; Bryman and Bell, 2011), this research deployed a series of methods, within an overarching framework. There were four key components:

1. comparative and content analysis and synthesis of different product stewardship schemes and programmes;
2. mapping of key UK precast concrete industry environmental and social impacts and the analysis of industry key performance indicators (KPI) data from 2006 to 2012;
3. identification of key structural and conceptual components of product stewardship in the UK precast concrete industry; and,
4. assessing the potential for PS implementation within the industry; and, developing and validating an EPD framework for the UK precast concrete industry.

All the research objectives, subject areas and the methods used were chosen to help the RE conduct robust empirical research which is cogent to helping the precast concrete industry solve one of its challenges of sustainability improvements. This also fits to the overarching aim of the EngD programme. The four research objectives and how they were met has been presented in figure 1.1, however, a summary is given in table 3.2.

Table 3.2 Linking the research objectives, subject areas, methods used and research outcome

Research objectives	**Research subject areas**	**Research method used**	**Research outcome**
Objective 1	Sustainability, sustainable construction, key precast concrete industry sustainability issues	Literature review and field survey (Precast concrete manufacturing site visits)	Paper 1 and Literature review document
Objective 2	Product stewardship (PS) schemes, exploring the potential of PS in the UK precast concrete industry	Interview survey, Questionnaire survey and literature review	Paper 2
Objective 3	Industry key performance indicator (KPI) statistics analysis and synthesis (2006 -2012) and mapping of precast industry environmental and social impacts	KPI statistics analysis and questionnaire survey	Paper 3 and industry survey report
Objective 4	Environmental product declarations (EPD) Design, development and validation of EPD framework development	Literature review, interviews and focus group	Paper 4 *(in draft)*

Each of the above used a specific research method, as presented in detail later, but as a useful preamble, the next section presents an overview of the key distinctions between qualitative, quantitative and mixed methods research designs.

3.4 QUALITATIVE RESEARCH

Denzin and Lincoln (2005:3) state that qualitative research '*involves the studied use and collection of variety of empirical materials*', including case study, personal experience, introspection, life story, interview, artefacts, cultural texts and productions, observational, historical, interactional and visual texts. Creswell (2008) argues that it involves a process of understanding an enquiry based on sound and distinct methodological traditions that explore a human or social problem and thus focuses on cases and contexts (Newman, 2006:151). It is an approach that examines people's experiences in detail, using a specific set of research methods (Hennink, 2011), such as in-depth interviews, focus group discussions, observation, content analysis, visual methods and life histories or biographies. However, Baker and Foy (2008) point out that qualitative research methods are viewed in some quarters as lacking in rigour and having indecisive outcomes. So the onus is on the researcher to present a robust approach which might rebut any such criticisms.

3.5 QUANTITATIVE RESEARCH

Quantitative research *"refers to approaches to empirical inquiry that collect, analyze, and display data in numerical rather than narrative form"* (Given, 2008 p.713). Quantitative research involves the use of mathematical, statistical and computational techniques through the process of an empirical investigation of social phenomena (because it describes pattern of behaviour and involves influences to the behaviour of the organism conducting the research for example; belief, reflexes, consciousness, alertness, feelings e.t.c.) conducted in a systematic way (Given, 2008). It focuses on measurement of variables and the process of hypothesis testing that have a link to general causal explanation (Neuman, 2006). Quantitative research, therefore, generates statistical information, often through the use of questionnaires or structured interviews in large-scale survey research (Dawson, 2002:15). Baker and Foy (2008) argue that this makes quantitative research methods more reliable and robust than the qualitative approach, which will lead to results and recommendations that are actionable and more acceptable. The challenge here is of course to ensure that sufficient data is gathered from which to draw robust, generalisable conclusions.

3.6 QUALITATIVE VERSUS QUANTITATIVE RESEARCH

Many authors have discussed the differences between qualitative and quantitative research approaches, how they happen to complement one another and are used to address various kinds of questions and goals (Maxwell and Loomis, 2002). One of the main differences between them is soft data (e.g. words, photos, etc.) and hard data (numbers), but Flick (2009) is of the view that both have their limitations. Bryman and Bell (2011) explained that the works of several authors have compared the different characteristics of qualitative and quantitative research approaches (e.g. Bryman, 1988; Halfpenny, 1979; Hammersley, 1992; MacDaniel and Gates, 1998). A recent and comprehensive table is shown below (Table 3.3).

Table 3.3: Some common contrasts between quantitative and qualitative research (Bryman and Bell, 2011: 410)

Quantitative	**Qualitative**
Numbers	Words
Point of view of researcher	Point of view of participant
Theory testing	Theory emergent
Static	Process
Structured	Unstructured
Generalisation	Contextual understanding
Hard, reliable data	Rich, deep data
Macro	Micro
Behaviour	Meaning
Artificial setting	Natural setting
Deductive	Inductive

These common contrast identified by Bryaman and Bell (2011) are generally accepted within academic literature; e.g the works of Miles and Huberman (1994, p.40) also agrees with table 3.2, which was also adopted by Neil (2007). During the course of the research both qualitative and quantitative research methodologies where used. Both methodologies where employed to help in achieving the set aims, objectives and research task identified as part of the research; this is discussed in section 3.6.1.

3.6.1 MIXED METHODS

Mixed methods or multi method research, as the name implies, is a combination of qualitative and quantitative research approaches. Tashakkori and Teddlie (1998:17) describe mixed methods as '*a combination of qualitative and quantitative approaches into a research methodology of a single study or multi phased study*'. It is commonplace for many research studies to include a number of different methods, but Tashakkori and Teddlie (1998) propose that a "truly mixed methodology" would incorporate multiple approaches in all stages of the study (i.e. problem identification, data collection, data analysis, and final inferences) and would include transformation of the data and their analysis through another approach. Hence, it may not be appropriate to label a study which simply deploys a number of methods as 'mixed' method unless there is some transformation taking place. Data transformation within the confines of this research means conducting series of scientific research investigations which were aimed at establishing robust analysis, synthesis and prognosis of the key components of the EngD research for example; After conducting the review of relevant literature, it was very clear that the industry has a sustainability strategy and other series of initiatives which focused on sustainability performance measurements (KPI data and industry targets) and improvements. The KPI data and targets set for the reduction of water, waste, cementititious materials etc. by the precast industry are predominantly quantitative, while the sustainability charter and other industry initiatives were mainly qualitative. This provided a future research platform for the EngD.

Based on these premise 'mixed methods' research approach was adopted for the research and consequently, the survey instruments (i.e questionnaire survey, interviews, focus group, literature reviews and field surveys) were used as part of the EngD research. The first survey instruments (questionnaire survey and interviews) were developed and approved by the EngD supervisory team and a pilot survey was conducted. Improvements were made to the initial set of questions etc. and the industry survey was rolled-out. The data obtained from these surveys were analysed, synthesised, interpreted and presented to the supervisory team of this EngD research (comprising of the academic supervisors and industry supervisors) and a final report was formally submitted to the Sustainability and Environment Committee of British Precast. Results from this primary research activities were submitted to the International Journal of Sustainable Construction (see Appendix C Paper 3).

3.7 OVERVIEW OF ADOPTED RESEARCH METHODS

Following a review of different research approaches, and taking into consideration the aim and research objectives, the research was directed and conducted within a set of work packages, as outlined in Chapter 1. Each of these was derived from a series of research questions generated from the research aim and objectives. The core principle behind the EngD is '*the solution of one or more significant and challenging engineering problems within an industrial context'* (CICE, 2013). The research methods employed to achieve the key objectives of the research include literature review, interviews, desktop case studies, surveys, analysis and synthesis of KPI data and focus groups. Each of the research methods used is described in the following sections.

3.7.1 LITERATURE REVIEW

Collins and Hussey (2003) suggest that the main purpose of a literature review is to provide proof of scholarship (i.e. build a general understanding and knowledge base about a subject area), but it should also provide an insight into the key issues (Lashley and Best, 2003). It should also summarise present or active research within the area through the identification of patterns, issues and conceptual content (Meredith, 1993). A literature review should also include an exploration of abstract concepts of explicit and tacit knowledge (Jesson *et al.*, 2011). To do so, Anthony *et al.,* (2009) note that a typical literature review should contain six steps: selecting a topic, searching for the literature; developing an argument, surveying the literature, critiquing the literature and lastly writing the review. The literature review was the first data collection tool used in this research and its use continued throughout the research to ensure that the Research Engineer (RE) was constantly up to date with the general subject area. Continuous work on the literature review also helped in probing specific themes and issues as they arose within the research process. The key sources were academic journals, peer-reviewed conference proceedings, text books, UK government and construction industry reports and company reports/websites.

3.7.2 QUESTIONNAIRE SURVEY

In a questionnaire survey, people's views, qualities and actions are collected to generate descriptive or explanatory data (Saunders *et al.,* 2012). According to Sekaran and Bougie, (2010:197), questionnaires are '*pre-formulated written set of questions to which respondents record their answers, usually within rather closely defined alternatives'*. Jankowicz (2005) listed four different techniques of interacting with respondents through questionnaires. These are face-to-face, postal, and electronic and telephone techniques. Questionnaire surveys can be can structured, semi-structured or unstructured; generally, structured questionnaires are designed to ask respondents the same sets of questions for the purpose of comparability.

In this research, a structured self-completion questionnaire was used as a survey method; in this format, respondents answer or complete sets of designed or pre-prepared questions by themselves (Bryman and Bell, 2007; Saunders *et al.*, 2007). The aim of the questionnaire survey was to understand the impact of managing the current sustainability issues and life-cycle management of the precast concrete industry as well as gauging precast manufacturers' views on PS. The survey provided robust evidence of the effective means and methods of developing consensus and facilitating progress towards the operation of PS within the precast concrete industry. The key findings from the questionnaire survey formed part of Appendix C (Paper 3).

3.7.3 INTERVIEWS

In this research, a questionnaire survey was combined with personal interviews. Haigh (2008) notes that qualitative interviews potentially help researchers to "generate insights, concepts and expand understanding", but a combination of semi-structured interviews with a self-completion questionnaire can be used to gain a better understanding on a given subject (Bryman and Bell, 2011).

Easterby-Smith *et al.,* (2008:143) describes interviews as the best method of gathering information. Gubrium and Holsteain (2001) assert that interviews are an information gathering procedure that brings experiences together narratively; alternatively they are simply defined as conversation (Kvale, 1996) or '*active interactions between two or more people, leading to negotiated, contextually based results'* (Silverman, 1997:98). The interview method can be applied to quantitative and qualitative research and can be used to gather quantitative and qualitative data (Knight and Ruddock, 2008). Denzin and Lincoln (1998:174) describe the relationship between the interviewer and the interviewee as a '*balanced rapport'*. Interviews can vary but can be classed into; structured, semi-structured and unstructured; they can be delivered face-to-face, through telephone, on-line or via email (Jankowicz, 2005; Sekaran and Bougie, 2010).

As part of the research, interviews were conducted with member companies of BPCF. The purpose of the interviews was to gain a nuanced, in-depth understanding of each individual member company's position on the key sustainability issues (as identified from their questionnaire survey responses), together with their thoughts on PS within their companies and the wider precast concrete industry. Interviews were also used to gather information about EPD. The interview results were used for Paper 2 (Appendix B) and paper 4 (Appendix D).

3.7.4 FOCUS GROUP

The focus group method is sometimes described as a group interview. Bryman and Bell (2011:503) explain that the focus group method has an emphasis on a fairly tightly defined topic and attempts to construct meaning through interaction within the group. As a result, the number of participants tends to be small, such that detailed discussion can ensue and be captured; a moderator facilitates the focus group to ensure it stays focused on the topic in hand (Saunders *et al.*, 2012:592). Finally, Morgan (1997) asserts that the focus group elicits and explores in-depth opinions, judgements and evaluations, so it is normally classified as a qualitative research method.

In this research, an EPD framework was validated through an industry focus group involving expert participants drawn from within the precast concrete manufacturing companies; the results and findings of this particular task are discussed in Chapter Four.

3.8 SUMMARY

This chapter has presented the research approach and overviewed the main research methods used. The key attributes of quantitative and qualitative research methodologies and mixed methods have been presented. The combination of literature review, questionnaire survey, interviews and focus group chosen for this research has also been discussed. The next chapter presents in detail the work packages undertaken during the course of the research, including the major results which emerged.

4. RESEARCH UNDERTAKEN

4. 1 INTRODUCTION

This chapter explains the research undertaken in relation to meeting the overall aim and objectives of the EngD research. The research was divided into five work packages (WP1 to WP5) and each work package is described in a separate section. Each of the five work packages culminates in a research summary, findings, or results which have both been published and presented in a conference and/or a journal publication. Each of the research papers forms an integral part of the EngD research; as such these should be read in conjunction with the thesis.

4.2 WP1–SUSTAINABILITY AND THE PRECAST INDUSTRY

The aim of WP1 was to understand the general context of the research area within the UK precast concrete industry. This was conducted as the first and foremost priority to gain a sound and in-depth understanding of the key issues in regards to sustainability and sustainable construction within the UK construction industry, concrete industry and the precast concrete industry. This included the UK government's approaches and the responses to these approaches by the concrete and the precast concrete industry and their respective supply chain stakeholders, the development of a precast concrete industry strategy and its implementation. WP1 was a longitudinal activity and served to underpin all the other WPs – its basis was in a review of academic and industry literature, combined with active participation by the RE in a wide range of industry-related seminars, events and committees (e.g. BPCF Sustainability Committee). Much of the output materials from WP1 was reported earlier as part of Chapter Two, so here, a summary of recent developments and evolution of the precast concrete industry's position on sustainability is presented, based on a review of industry and academic literature; it is also documented in Paper 1 (Appendix A).

Precast concrete as defined by (Elliot, 2002:1) is "concrete which has been prepared for casting, cast and cured in a location not its final destination". Another clearer definition is; Precast concrete products are made in factories, transported to sites or cast on construction sites but remote from point of use (Clarke and Glass, 2008:2). The UK precast concrete industry is an important national industry. According to Holton (2009), precast concrete production in terms of tonnage stood at over 35 million tonnes of products annually, worth in excess of £2.5 billion and around 22,000 employees in 800 precast concrete factories in different geographical locations in the UK (Sustainability Matters, 2008; Sustainable Concrete, 2009).

According to Holton (2009), the UK precast concrete industry recorded major achievements on sustainability from 1999 with the formation of Environment, Health and Safety committees to provide a pan-sector approach in dealing with important sustainability issues facing the industry. By 2001, the Concrete Targets Award scheme was launched (HSE, 2009); this was in a rapid response to the Government's 'Revitalising Health and Safety' initiative. The target was to drastically reduce accident rates within the industry and to improve Health and Safety across the length and breadth of the country. In 2002, the Best Practice Award was initiated to promote excellence and recognise members that have made progress on innovation, health, safety and the environment. In the same year, the BPCF joined the DEFRA and DTI pioneers group to demonstrate its commitment to developing a sector sustainability strategy for the precast concrete industry. In 2003, BPCF's council approved the sponsorship of an Engineering Doctorate (EngD) in the Department of Civil and Building Engineering, Loughborough University to develop a sector sustainability strategy for the precast concrete industry (BPCF and Construction News, 2008:4).

In 2005, a joint approach to sustainability from the cement and concrete industry was facilitated by the Concrete Sector Sustainability Working Group and 10 key sustainability issues facing the industry were identified in a workshop. The UK precast concrete industry devised its sustainability programme, 'More from Less' in 2004 to address these sustainability issues. Still on-going, the programme was purposely aimed at measuring, improving and promoting the environmental, social and economic credentials of precast concrete products in the UK. As a result, a sector sustainability strategy was developed and implemented (Holton *et al.*, 2009). An industry verification survey using a questionnaire to ascertain the 16 key sustainability issues identified by BPCF was conducted in 2006 by Holton (2009). Figure 4.1 demonstrates the 16 key issues. Finally, a sustainability programme was approved by the BPCF Council in 2007 to improve performance across the whole precast concrete industry on sustainability, including:

- key performance indicators;
- sustainability charter;
- certification scheme;

- best practice forum; and,
- objectives and targets for improvement.

The sustainability charter was purposely launched to engender commitment of all BPCF member companies to a designed set of sustainability guided principles (BPCF and Construction News, 2008). In 2008, an industry consultation and charter audits, to encourage the BPCF's members to go beyond legislation and to take deliberate actions in making their products and operations more sustainable, was conducted.

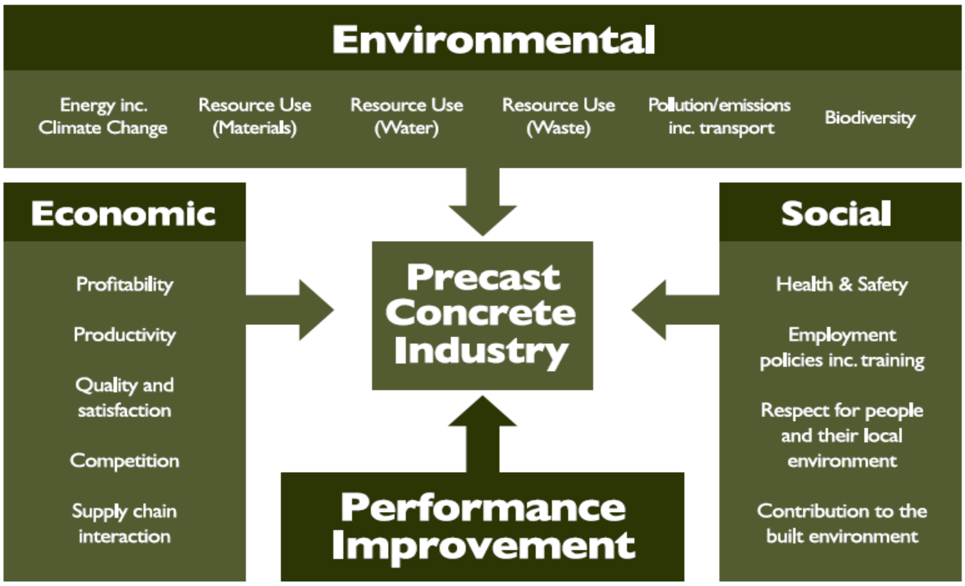


Figure 4.1: 16 priority sustainability issues in the precast concrete industry (Holton, 2008:2).

The preceding narrative demonstrates a clear commitment and progress by the BPCF and its member companies to address sustainability within the precast concrete industry (based on some of the precepts discussed earlier). Certainly, the UK precast concrete industry has developed its own sector strategy to measure and improve its sustainability performance including; a sustainability charter, setting of key objectives and targets for improvement, and key performance indicator data. These nest within a whole concrete industry approach, which in turn responds to relevant government sustainable construction targets (BERR, 2008). Hence, the precast industry has established a sound approach which has been proven to deliver relevant data, respond to national initiatives and be sufficiently palatable to its member companies to participate and seek 'chartered' member status. That said, it has been under increasing pressure. There are growing legal and commercial pressures on the entire UK construction industry to become more sustainable (Bennett and Crudgington, 2003). Various stakeholders within the construction industry have recognised the need for a major change in the sustainability of the UK construction industry (BERR, 2008; 2009). So, further steps could be taken by industry to improve the level of 'responsibility' being demonstrated throughout the life-cycle of precast concrete products, thereby extending the influence of the precast concrete manufacturers to upstream and downstream sustainability impacts. It was for this basis that WP2 on Product Stewardship was formulated, as described next.

4.3 WP2– CONCEPTUALISING PRODUCT STEWARDSHIP (PS)

Following on from WP1 which focused on the general understanding of sustainability, sustainable construction, EPD and the precast concrete industry, WP2 focused on conceptualising PS in the context of the UK precast concrete industry, through a literature review (presented in part in Chapter Two) and then the development of a set of interpretive and generic models (the development process is explained in 4.3.2 and the models presented in Appendix G) that was used in subsequent WPs during the data collection and analysis phases. The summary of the key findings are presented here and also documented in Paper 2 (Appendix B).

4.3.1 THE KEY COMPONENTS OF PS

From the literature review presented in Chapter Two, existing academic and industry literature and evidence suggests that PS encompasses environmental, social and economic issues, but this does not sufficiently capture all the dimensions within commonly-used definitions of PS (see Table 2.2). Rather, an overarching model for PS should note that it encourages businesses to become more responsible through proper ethical management and helping businesses to reduce cost and liabilities (Johnen *et al.*, 2000). PS schemes help stakeholders within businesses, companies, organisations and multinational corporations to mitigate the environmental impacts associated with products throughout the entire life cycle from 'cradle to cradle' by taking responsibility to address such impacts. The four key components of PS are thus shown in Figure 4.2 and a more detailed conceptual framework for the key components in PS is shown in Figure 4.3.

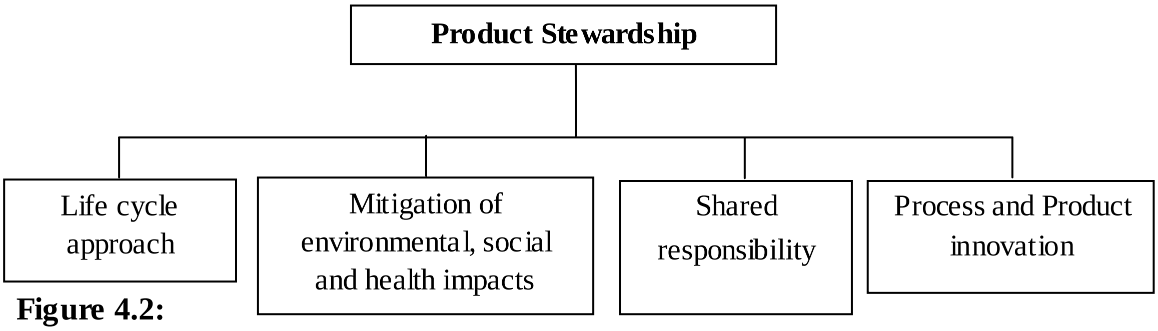


Figure 4.2:
Key structural components of PS, adapted from secondary and primary sources.

The key structural components of PS adopted from literature were obtained through a combination of primary and secondary research data i.e state-of-the art desktop literature review and survey, consequently by;

1. Extracting the four key terms directly or words closely related to the subject from different PS definitions as defined by various key stakeholders within the PS discourse (see table 2.2);
2. Section 2.4 and 2.5 where a general overview of selected PS schemes was given, from desktop literature reviews (i.e academic journals, industry reports and internet sources); and,
3. From primary research data from the precast concrete industry surveys (questionnaire survey and interviews) conducted. These keywords do not appear in all the definitions used as such groups where created and replicated as the occurrence of the key words appeared. Table 4.1 shows the relevant keywords and words closely related to the subject that makes up the structural components of PS.

These research activities as shown in table 4.1 and table 4.2 further feed to figure 4.3 and the key structural components of PS documented in appendix B paper two.

Table 4.1: Relevant keywords that make up the structural components of PS obtained from secondary sources

Keywords or terms that make up the structural components of PS	Secondary sources			
	Industry reports	**Websites**	**Textbooks**	**Academic journals**
1. Life cycle approach	OECD, 2005; PSI, 2010:1; NWPSC, 2010: 1; PSF, 2010: 1	US EPA, 2013:1	Bruijin in Visser et al., 2007: 378; Madu, 2007:99; Ryding, 1998: 665	Hart, 1997:71; Hart, 2007:69
2. Mitigation of;				
Environmental impacts	OECD, 2005; PSF, 2010: 1; HP, 2010; Toyota, 2010;	US EPA, 2013:1; IBM, 2010	Madu, 2007:99; Bruijin in Visser et al., 2007: 378; Ryding, 1998: 665	Hart, 1997:71; Hart, 2007:69; Lewis, 2010: 196;
social impacts	PSI, 2010:1	HP, 2010;	Fiskel, 2009;	Palmer and Walls, 2002;
Economic impacts	-	GPSC, 2014; Hart and Milstein, 2003	Fiskel, 2009;	Hart, 1997:73; Palmer and Walls, 2002; Johnen *et al.*, 2000; Hart and Milsten, 2003
3. Shared stakeholder responsibility	OECD, 2005; PSI, 2010:1; NWPSC, 2010; PSF, 2010;	US EPA, 2013:1	Pitchell, 2005:641;	Lewis, 2010: 196.
4. Process and Product innovation	NWPSC, 2010; PSF, 2010: 1; Ryding, 1998: 665; Diamler, 2010; Caterpillar (2010); Toyota, 2010.	Motorolla, 2010; IBM, 2010; Philips, 2010; Dell, 2010.	Brady *et al.*, 1999; Armstrong and Kotler, 2006; BASF, 2010, Fiskel, 2009	Hart, 1997:71; Hart, 2007:69; Lewis, 2010: 196.

Table 4.2: Keywords or terms that make up the structural components of PS from primary sources (i.e surveys)

Keywords or related terms that make up the structural components of PS	Primary sources through precast concrete industry surveys	
	Interviews	Questionnaire survey
1. Life cycle approach	Company 1; Company 2; Company 4; Company 5; Company 6; Company 7	-
2. Mitigation of:		
Environmental Impacts;	Company 8; Company 12	Company 3
social impacts; and,	Company 8; Company 12	Company 3
Economic impacts	Company 8; Company 12	-
3. Shared stakeholder responsibility	Company 1	-
4. Process and Product innovation	Company 4, Company 10	Company 3

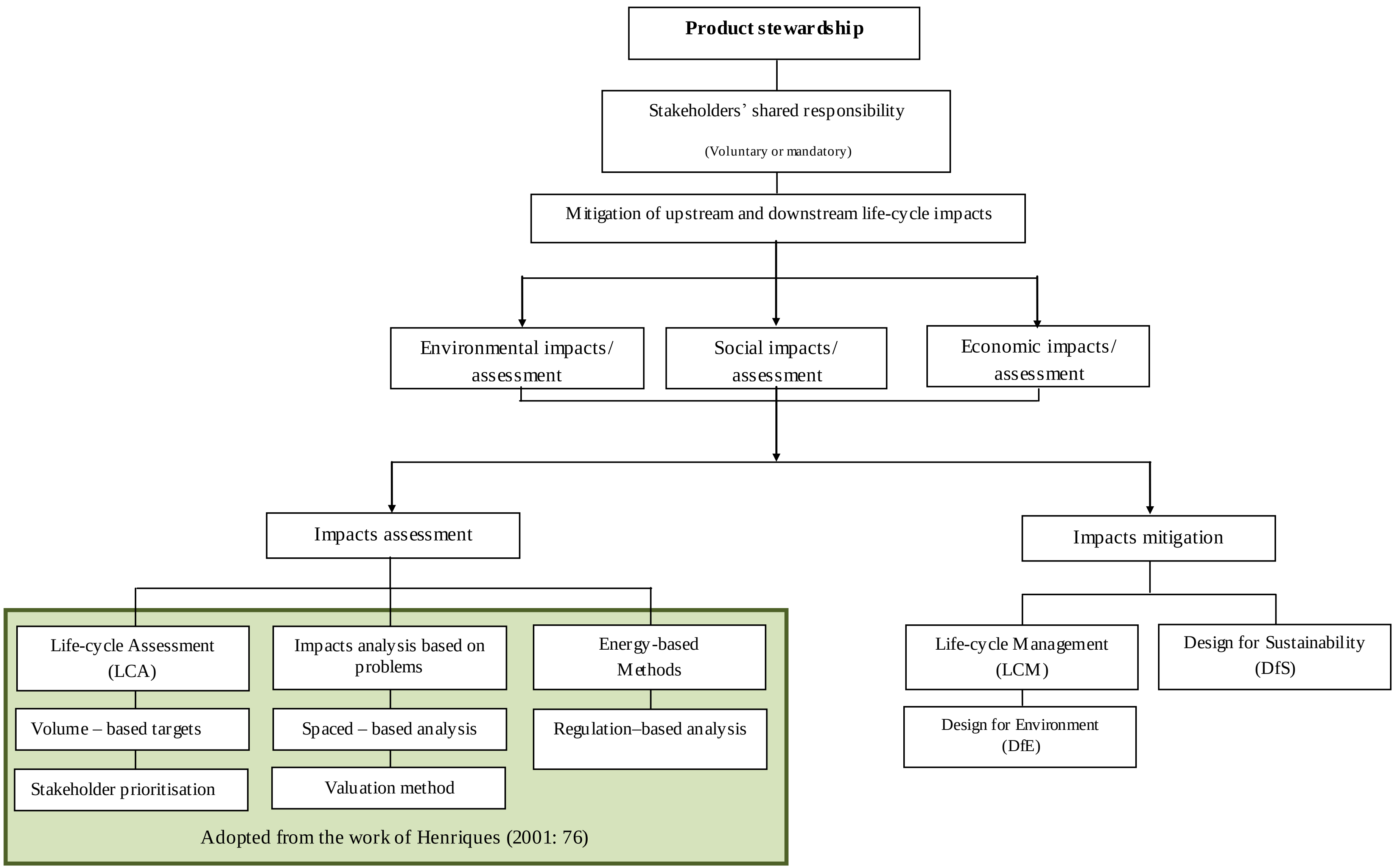


Figure 4.3: Product stewardship process tree adapted from literature.

Development of the PS process tree

All the terms and key works used for the PS process tree in figure 4.3 where obtained from both primary and secondary sources which was the same procedure used in developing the four key component of PS. An explanation and definition will be given to some of the terms within the process tree.

Product stewardship is the key concept and an integral concept of this EngD research, as explained in chapter one and defined in chapter two.

Precast concrete industry stakeholder holders

Within the UK precast concrete industry, there are various stakeholders upstream and downstream the supply and value chain. All the stakeholders involved with precast concrete product(s) from souring of the constituent material, manufacturing, transportation, operational use, and end-of-life are all classed as stakeholders. This list is none exhaustive; however it gives a good picture of the situation. The individual or collective responsibility of each stakeholder will be discussed below.

Client – Any person who has legal right of ownership or delegated responsibility on a precast concrete product or element(s).

Designer – the person (s) responsible for designing precast concrete product or element(s).

Manufacturer – Is someone that produces different types of precast concrete product or element(s).

Users – Anybody that own and use a precast product, element or building throughout its service life or end-of-life.

Shared responsibility is the process of apportioning responsibility of a precast concrete element or product. It is shared amongst agreed stakeholders either voluntary or mandatory.

Mitigation of upstream impacts and downstream life cycle impacts

This is the process of reducing the upstream and downstream life cycle impacts across the whole life cycle of a precast concrete product(s).

Broadly speaking, mitigation of upstream and downstream impacts can be grouped into three, which include; environmental impacts, social impacts and economic impacts.

Environmental impact: can be defined as "change to the environment, whether adverse or beneficial, wholly or partially, resulting from environmental aspects". BS EN 15978 (2011:9).

Social impact: According to Vanclay (2002:388), social impact be defined as:

"*….the intended and unintended consequences on the human environment of planned interventions (policies, programs, plans, projects) and any social change processes invoked by those interventions so as to bring about a more sustainable and equitable biophysical and human environment".*

Economic impacts: Weisbrod and Weisbrod (2002), define economic impacts as;

"*effects on the level of economic activity in a given area. They may be viewed in terms of: (1) business output (or sales volume), (2) value added (or gross regional product), (3) wealth (including property values), (4) personal income (including wages), or (5) jobs"*.

The next stage within the PS process tree is:

Impact Assessment: *"Is a term that describes a portfolio of techniques that may be used to prioritise the environmental social and economic impacts which an organisation will pay particular attention".* (Henriques, 2001).

Impact mitigation: Is the procedure or practice of avoiding or partly offsetting impacts through efficient adaptation policy (Jamet and Corfee-Morlot, 2009).

With regards to mitigation, three key concepts were identified which include:

Life cycle Management (LCM): Fiskel, (2009:197) provides a definition of LCM as "systematic consideration of all life cycle stages in the evaluation, management, and improvement of an enterprise's product, services, process and assets". A similar definition is that of United Nation Environment Programme (UNEP, 2014) which defines LCM as a *"product management system aiming to minimize environmental and socio*-economic *burdens associated with an organisation's product or product portfolio during its entire life cycle and value chain".* UNEP further explains that LCM should not be viewed as a single methodology or tool, but rather a system that manages the collection, structuring and dissemination of product information from different types of systems, processes, programs, tools e.t.c while integrating life cycle socio-economic and environmental characteristic of products. In the case of precast concrete products, BS EN 15804:2012+A1:2013 provide general Life cycle information of a building which also is applicable for precast concrete products/ elements.

Design for Sustainability: This focuses on how industries focus on long term social, environmental and economic issues as their key area of product innovation strategy from a life cycle perspective and its supply chain (D4S, 2007).

Design for Environment: Conrad and Lagerstedt (2011) opined that the minimization of environmental and economic cost to customers is the main focus of design for environment. It considers the entire life cycle of a product or material and its potential environmental impact from extraction to disposal (Bevilacqua *et al*., 2012).

4.3.2 DEVELOPMENT OF GENERIC INTERPRETIVE PS MODELS

Following on from the desk-based analysis (from literature review see summary in figure) which resulted in figure 4.2 and 4.3 depicting PS, it was possible to draw on the detailed information about the various mandatory and voluntary PS programmes, outlined in Chapter Two, to develop generic, interpretive models of how PS is implemented in a range of different industries (and hence more easily convey the typical structural and conceptual components of PS in later work packages).

4.3.2.1 BASIS FOR THE FOUR MODELS

The models are generic and representative of the industry they relate to, which is typically a graphical representation (see Appendix G). They were all developed from desk –top internet searches (looking at different companies and organisation) the study of the various industry supply chains in Chapter 2 Section 2.4 and 2.5. The major differences of the four models is given in Table 4.3 and a summary of each of the four industries studied were presented in Tables; 2.3, 2.4, 2.5, 2.6 and 2.7 all provide the basis of the following four models:

- Model 1 - Automotive industry
- Model 2 - Oil and gas industry
- Model 3 - Packaging industry
- Model 4 - Electric and electronic industry

The interpretive models are representative of supply chains for a range of product or products within a particular industry, but the generic aspects include; raw material extraction/supply, design, manufacture, retail, use and end-of-life (and hence bear some comparability, if not similarity, to the precast concrete manufacturing industry). Any relevant legislation that provides the basis of PS implementation within each of the models was also identified, as well as their respective stakeholders. The models were used as part of the research instruments and shown to companies that were interviewed as part of the WP4, discussed later in this chapter.

Model 1 represents the generic automotive industry. The major regulation behind these models is the ELV Regulation 2010. All vehicles are sourced from different raw material suppliers. Usually, designers and manufacturers are under the same umbrella and based on ELV car manufacturers and end users are responsible for take-back at the end-of-life of the vehicle. But must companies liaise with retailers for wholesale and retail and ultimately the final users get the vehicle (cars, trucks, tractors e.t.c). The remit of responsibility as enshrined in the ELV regulation is that car makers should take the responsibility of their cars at the end-of-life (through take-back and disposal) and users are responsible for take-back. Due to the nature of use and advance in technology, electric and electronic equipment have a shorter life span. Approximately say maximum 20 years

Model 2 represents the chemical and petrochemical industry (for example petrol/ gas). The oil and gas industry for example sources its products from crude oil (refining) after prospecting and exploration. Basically, the process after refining of crude oil produces different products such as petrol, diesel, and kerosene e.t.c. The supply chain consist of major oil companies such as BP, Shell, Mobil, Chevron and Total Elf e.t.c which in some cases are the raw material suppliers (crude oil), manufacturer (refining), transporting (through pipeline or trucks), wholesale or retail (i.e distributors, marketers and sales). Once the product is sold, its lifecycle ends mainly through combustion in motor engines for petrol based vehicles or electric generating sets. With the oil and gas industry mainly the manufacturer and users are the main stakeholders for the use of the product. The government serves as the regulator. This product based on majority usage normally has the shortest life span amongst the four industries studied.

Model 3 shows a generic life cycle flow of a carton packing from sourcing of raw materials, design of the carton, production, end user and disposal/waste. This model shows a typical example of a packaging industry cycle. The key remit of responsibility lies with the manufacturer and users. The EU directive on packaging and packing waste/ producer responsibility obligations of 1994 serves as a legislation guiding this model. For example, in the UK it is mandatory for stakeholders (e.g importers, manufacturers, businesses) that handle more than 50 tonnes of packaging per annum and with a turnover of more than £2 million per annum to recycle their waste.

Model 4 shows how a typical product life cycle for e.g a printer or desk top computer from the electric and electronic industry. The relevant legislation guiding the electronics industry is the WEEE Directive 2002/96/EC which has now been revised to WEEE Directive 2012/19/EU. For a printer, the normal life cycle flow starts with raw material supply, design/ product manufacturing, retail and end use/ disposal. Basically, the whole life cycle has four key stages. The main responsibility of tack back lies with the final user of the product and recycling lies with the product manufacturer or their appointed agents.

Relating these models to the precast concrete industry

Looking at each of the four models, there are similarities and peculiarities as described in Table 4.3. The UK concrete industry has a similar life cycle stages with all the four models but with individual differences. The concrete industry has more life cycle stages (i.e research and design, raw material extraction, production, transportation, in-use, end-of-life, demolition and reuse/ recycling) and a longer design life span that all the products in comparison. For example in the case of gas or petrol (Chemical industry), there is a need for crude oil exploration and refining whereas in the concrete industry the is no need for refining.

However, the remit of responsibility lies with the manufacturer and user in the chemical industry. In terms of the four models' level of appropriateness to the concrete industry, it is pertinent to note that there study is useful to the concrete industry for example; lessons can be learnt on the effect of legislation on stakeholders, how stakeholders share and manage their remit of responsibilities, successes recorded in terms of cost saving, investment in infrastructure, contracting work to consultants, recycling facilities, logistics e.t.c. For the precast concrete industry, the key area of contention may be the degree to which each stakeholder shares or take responsibility, concrete's life span, and the practicality of development and implementation. That said, Model 1 provides a close life cycle flow with that of concrete based on chapter four, section 4.4.1 (Optimat, 2008 and CEMBUREAU, 2008). These key stages in Model 1 include; raw material supply, design of product, product manufacture, retail, use/end user.

Identifying precast concrete stakeholders

In the UK precast concrete industry, the key stakeholders within the precast product life cycle are; the raw material supplier, designers, clients/ users, manufacturers, consultants, government.

Raw material suppliers: are upstream stakeholders listed in table 2.1 (CISCF, 2008) which includes; aggregate extractors, cement producers (e.g CEM 1), manufactures of additional cementitious materials (e.g GGBS, fly ash), steel manufactures, chemical manufactures.

Designers: these are downstream actors e.g architects, engineers, specifies e.t.c.

Clients/ users: these are the legal owners, users or their appointed representatives.

Manufacturers: are precast concrete production companies.

Consultants: are individual(s), group (s) or organisations that have been appointed to provide professional work related to concrete and or any part of its life cycle.

Government: the official body or organisation(s) that serves as a local or national UK authority.

Description is given below on linking these key precast concrete stakeholders with figure 4.2 and 4.3:

Figure 4.2; for the precast concrete industry, adopting the four key components of PS means the a life cycle approach mitigation of environmental, social and health impacts through shared responsibility, product and process innovation.

Figure 4.3:

Shared responsibility will be the duty of all the key stakeholders (i.e raw material suppliers, designers, clients/ users, manufacturers, consultants and government).

Mitigation of upstream impacts (by all raw material supplier) and downstream impacts (by designers, manufacturers, user and end users) is the responsibility of the relevant stakeholders. These impacts are divided into three; environmental, social and economic impacts. All these are the responsibilities of both upstream and downstream stakeholders. These impacts can be assessed based on the works of (Henriques, 2001:76) and the mitigation of such impacts can be through LCM, DfE or DfS.

Table 4.3: Differences between the four generic models

Models	Mandatory or voluntary	Literature source	Directive/ legislation or similar	Date of implementation	Products covered by the directive	Example of companies involved	Stakeholders involved	Coverage i.e countries where exact or similar legislation is applicable
Model 1 – Automotive industry	Mandatory	EC, 2010a; Fiskel (2009); Toyota (2010); Diamler (2010) and Caterpillar (2010).	End-of-Life of Vehicles ELV's Directive (2000/53/EC)	2000	Vehicles	GM Motors, Toyota, Daimler AG (Mercedes Benz), Caterpillar	Car manufacturers and end users	Europe, Japan, USA, Canada, Australia, New Zealand
Model 2 – Chemical and petro chemical	Voluntary	ICCA, 2009, 2010; BASF, 2010; Dow Chemical, 2010; DuPont, 2010; Responsible Care, 2010; Fiskel, 2009 and Shell Chemical, 2010.	Responsible Care Global Charter (RCGC) and the Global Product Strategy (GPS) as part of United Nations/ Strategic Approach to International Chemicals Management (SAICM)	1980s	Chemicals	Dow Chemical, DuPont, BASF, Shell Chemicals	Staff, suppliers, retailers, wholesalers	US, Europe, Japan, Canada, Australia, New Zealand
Model 3 – Packaging industry	Mandatory	BERR (2010); EC (2010); Palmer and Walls (2002); EC, 2010b,	Directive 94/62/EC	1992	Packaging waste	Packaging companies	Manufacturers	Europe, Japan, USA, Canada, Australia, New Zealand
Model 4 – Electric industry	Mandatory	Fiksel, 2009; Motorolla, 2010; Dell, 2010; Davis, 1996; IBM, 2010; Microsoft, 2010; HP, 2010 and Philips 2010.	Directive 2002/96/EC of the European Unio (EU), RoHs 2002/95/EC 2003	2003	Obsolete, disused, scrap, faulty or unwanted electronic devices or equipment	Hewlett Packard, Motorolla, Dell, IBM, Microsoft, Sony Corporation, Xerox, Philips	Producers (any business that manufactures, imports or rebrands electrical and electronic products); Retailers and Distributors (any business that sells electrical and electronic equipment to end users); Local authorities; Waste management industry and Exporters and re-processors Business and other non-household users of EEE.	Europe, Japan, USA, Canada, Australia, New Zealand

4.4 WP3 – MAPPING KEY INDUSTRY IMPACTS

The main aim of this work package was to identify or map out the key sustainability (i.e. environmental, social and economic impacts) that are pertinent to the concrete industry, focusing on those of particular relevance to the precast concrete manufacturing process and life-cycle. The summary of the key research findings are presented here and the full contents are documented in Paper 2 (Appendix B).

4.4.1 UNDERSTANDING CONCRETE'S SUSTAINABILITY ISSUES

Based on the sustainability strategy developed for the precast industry, 16 priority sustainability issues within the industry were clearly identified (see Figure 4.1), all of which were useful in understanding the industry's recent and current priorities in respect of environmental, social and economic objectives. The relative priority and scale ascribed to each would also be informative in establishing any particular 'hot spots'. According to literature, the life cycle of concrete consist of various stage from raw material mining or sourcing to the end –of-life stages (CEMBUREAU, 2008 and Optimat, 2008); prior to discussing the impacts in detail, it is important to set these within a broader context, i.e. the generic life-cycle for concrete, as shown in Figure 4.4.

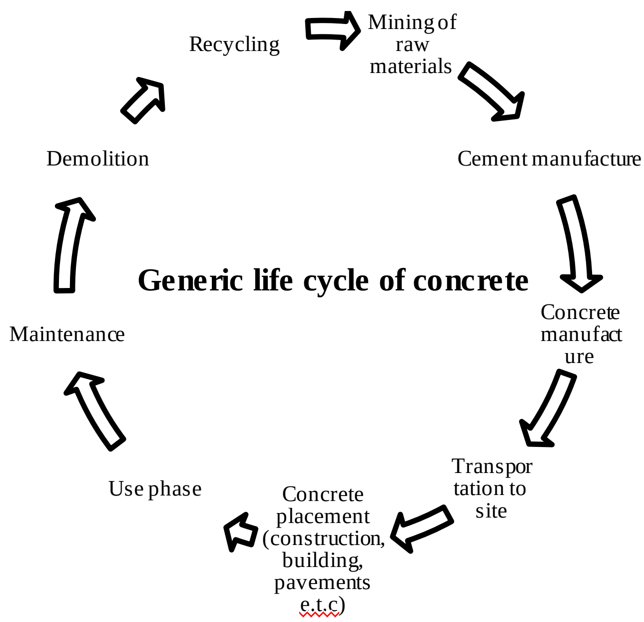


Figure 4.4: Generic life cycle of concrete.

Within the concrete industry, regardless of production/placing method (i.e. in-situ, precast), the key environmental and social impacts of concrete can be considered as occurring across six main stages, based on the life-cycle process shown above (Optimat, 2008); these are:

1. raw material extraction;
2. cement and addition manufacture;
3. production of ready-mixed concrete and precast products;
4. construction of buildings and infrastructure using concrete;
5. operational use in the built environment; and,
6. end-of- life disposal and recovery.

Within the sustainability field, Life cycle assessments are carried out to understand all impacts with the entire product life cycle. According to ISO 14044(2006), An LCA "is the compilation and evaluation of inputs and outputs and the potential environmental impacts of a product system during its life time". ISO14040 (2006:V) argues that life-cycle assessment: '*...addresses the environmental aspects and potential environmental impacts (e.g. use of resources and the environmental consequences of releases) throughout a product's life cycle from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal (i.e. cradle-to-grave)".* Yet the complexity of accounting for life-cycle emissions, such as CO_2, SO_X, and NO_X among others (Bijen, 2002), has genuinely confounded major sectors, like the UK concrete industry in finding ways and methods to reduce its impacts meaningfully across multiple life-cycle phases (Parrott, 2002). According to Cement Sustainability Initiative (CSI, 2012) and Collins and Sanjayan (2002), five percent of all man-made CO2 emission are as a result of global cement manufacture" Cement production in the UK has also been identified as the largest CO2 emission source within the concrete industry. In the UK precast concrete industry, upstream the supply chain, next to cement; the precast concrete manufacturing has the highest impacts. Downstream the supply chain, the in-use phase or service life has a higher CO2 emission that the precast concrete manufacturing phases.

From a broader perspective, within the UK construction industry which includes all industries steel, aluminium, glass, concrete, wood and others; according to the Department of Business, Innovation and Skills (BIS) (2010:4) Innovation and Growth Team (IGT) report on estimating the amount of CO_2 emissions that the construction industry can influence

(influence means the potential of the construction industry to make an effect, impact or trigger a change), manufacturing accounts for the largest source of CO_2 emission within the industry, and accounting for around 15% of total CO_2 emissions. This suggests that the manufacturing and in-use phase constitute 15% and 82% respectively; this adds up to 97% of the total CO_2 emissions which the construction has ability to influence.

A calculation methodology which looked at the whole building life cycle was devised. This methodology include all the generic life cycle of a building from design, materials or product manufacture, distribution, assembly, in-use and refurbishment/ demolition. Figure 4.5 shows all sources of CO_2 emissions.

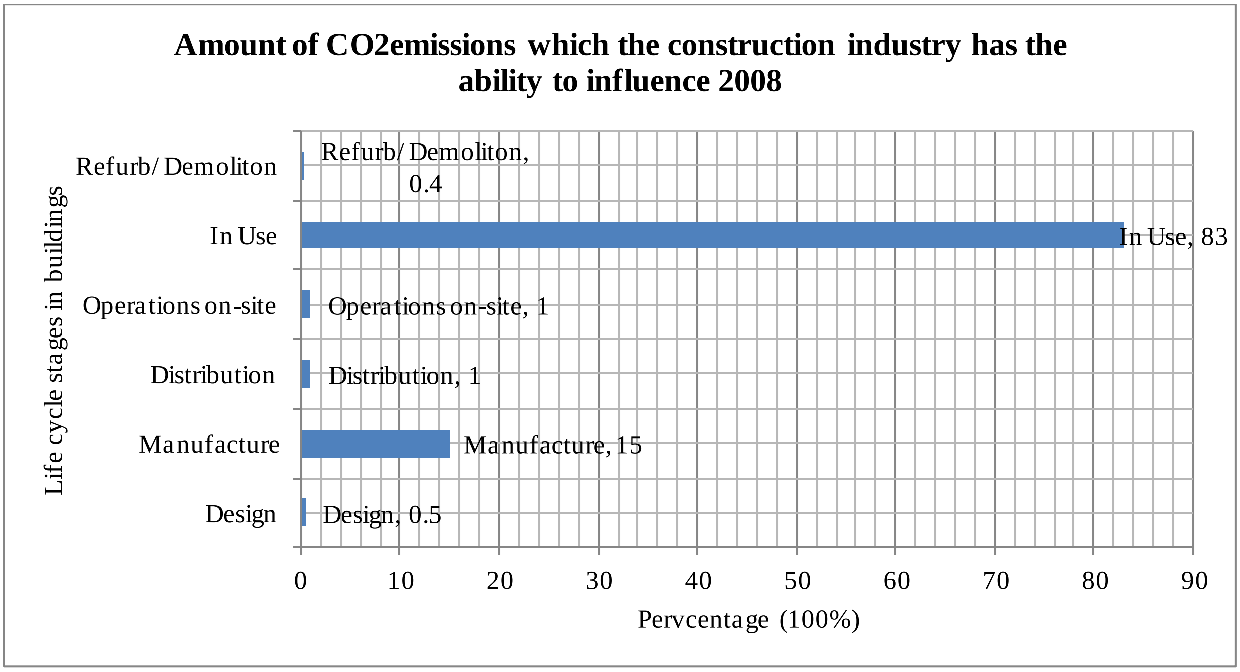


Figure 4.5: Amount of CO_2 emissions which the construction industry has the ability to influence (The bar graph was *generated from* BIS, 2010:4)*.

The key findings from the IGT report (BIS, 2010) takes into cognisance of all the key life cycle stages in figure 4.5, the summary of the findings are:

1. The UK construction industry can have an make an impact on the amount of carbon (CO2) emissions within the industry as it account 47% of the total UK's carbon emissions;
2. The in-use phase of the building emission constitute 80% of the total carbon emission that the construction industry can have an effect on; and,

3. Manufacturing process (construction products and materials) has the largest amount within the construction process.

However, the last decade has seen significant improvement in the understanding of the environmental impacts of concrete throughout the entire life-cycle.

That said, without doubt the largest environmental impact from concrete arises from the inclusion of Portland cement in the product (Sakai, 2008), which is energy-intensive in its manufacture and so incurs a significant burden, namely in terms of carbon dioxide emissions. This dominance is also consistent for all 'legacy' products (construction or building products that contains calcium carbonate and aluminium silicate) which contain cement, including precast concrete, although transportation does assume a slightly greater proportion of precast concrete's impacts, compared to ready-mixed concrete (Bijen, 2002).

The major environmental impacts associated with precast concrete products are therefore embodied environmental impacts (resulting from constituent raw materials – including cement, manufacturing energy and water consumption, and physical waste) (Elhag *et al.*, 2008), other impacts relate to economic and social issues.

4.4.2 ANALYSIS OF INDUSTRY KEY PERFORMANCE INDICATORS (KPI) DATA FROM 2006-2012.

Given the above context, the main research task in WP3 was to analyse the key industry performance indicators (KPI) data from 2006-2012 – as mentioned in section 4.1, the KPI data underpins the whole concrete industry's approach to managing and reporting its sustainability impacts.

According to the KPI Working Group (2000:7) 'The purpose of Key Performance Indicators (KPIs) is to enable measurement of project and organisational performance throughout the construction industry'. The report further explains that KPIs help organisations and companies within the construction industry supply chain to be able to benchmark their performance, identify strengths and weaknesses, and assess their ability to improve over time. CIRIA (2001:16) defines indicators as quantitative measures of performance; they focus on organisational performance matters that are key to both the current and future success of an organisation (Parmenter, 2007).

Presently, the UK precast concrete industry collects data for environmental and social issues and related impacts. Due to sensitivities of economic data, this has not been included since the inception of precast concrete industry KPI data collection from 2006 to 2013. In 2006, as part of a previous EngD research (Holton, 2010) and in collaboration with British Precast's Environmental consultant and BPCF member companies, the first set of data was collected and for then onwards; these data has been collated by the precast concrete industry environmental consultancy team at British Precast and with permission, has been used for the purpose of this EngD research. These data was obtained from BPCF Sustainability Matters and reports from 2007 to 2013. Data was collected from all BPCF Charter member signatories (ranging between 19 to 27 companies), based on their submissions for seven calendar years (2006-12); these companies account for around half of all precast concrete production in the UK. The KPIs are a set of quantitative data that reflects the precast concrete industry`s performance on all the sustainability issues facing the industry, including productivity, quality and satisfaction, resource use, Health and Safety, pollution, employment policies, respect for people, energy (including climate change), productivity, quality and satisfaction, and emissions (Holton, 2008). The importance of this data to the research lies in the following:

- it provides an overview of performance against key social and environmental indicators; and,
- it supports the industry's accepted methodology for gauging the sector's performance over time.

It is important to note that the industry KPI data consist of environmental and social issues related data. However, since sustainability has three pillars to which economic is one of such, it will be of great benefit to include economic issues/ impacts data in future KPI data analysis. World leading organisations globally have recognised the importance of economic data being an integral part of sustainability reporting. Such links can be seen in organisations that provide strategy such as; the Global Reporting Initiative (GRI) and SustainAbility to world leading organisations for example; Bayer, Nestle, HP and Ford. As such the industry will benefit if all the three pillars of sustainability are reported in future KPI data analysis and disclosure. This will mean the availability of balanced and transparent information that is publically available and accessible with enhanced openness, accountability and transparency.

A summary of the industry KPI data from 2006-2012 is shown in Table 4.4. And a detailed description is given below to support table 4.4. It is clearly shown that on specific issues for example;

1. **Number of companies providing data**; there was an increase in the number of companies that provide KPI data to British Precast from 2006 to 2012. From figure 4.6, at the inception of KPI data collection in 2006, 19 companies provided data. From 2007, the numbers increased to 25 with six companies. Between 2008 to 2011 there was little change with just one company added in 2008 and 2009. And the number decreased with one company opting out in 2009. These can all be attributed to the expansion and contraction of the industry during the 2008 economic recession experienced in the UK. Some companies within the industry left membership of BPCF and other companies joined or re-joined at certain points during the course of the years. The number of companies providing data reached its highest in 2012. This may be attributed to the requirement of being a sustainability charter signatory and which has a condition for the submission of KPI data for performance monitoring by the industry.

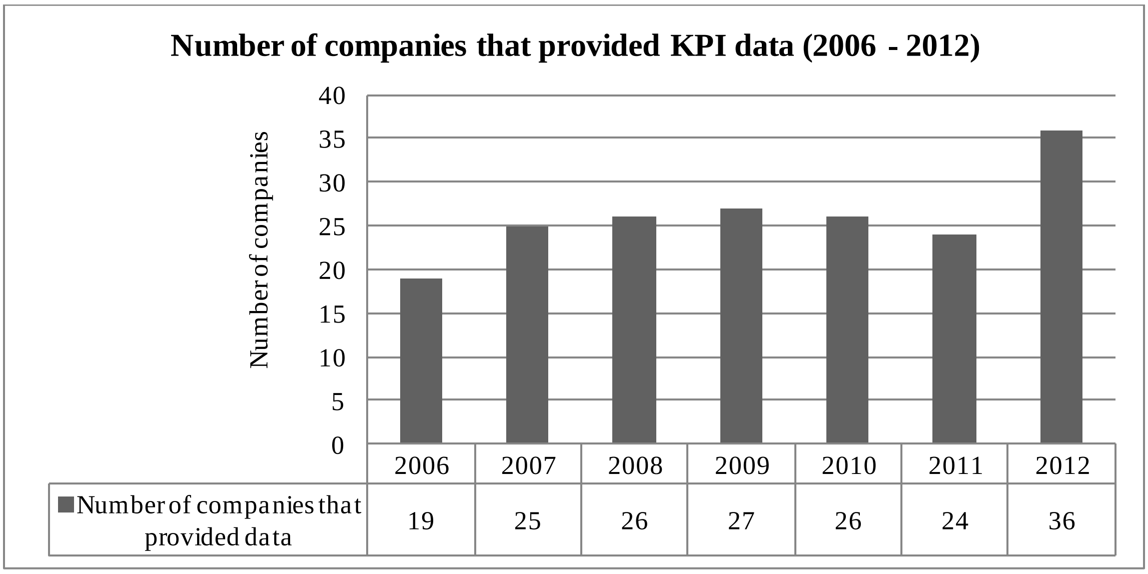


Figure 4.6: Number of companies that provided data from 2006 to 2012 in the UK precast concrete industry

2. **Number of production units (factories);** within the precast concrete industry experienced a major dip from 132 in 2006 to 121 in 2012. As shown in figure 4.7, the year 2009 had the highest number of precast concrete factories with 135 since the

beginning of data collection in 2006. The reduction in the number of factories was due to closures, mergers and acquisition. This can be attributed to the fact that there was a contraction in the industry with many factory closures up and down the country. However, 2009, there was a record high in the number of factories.

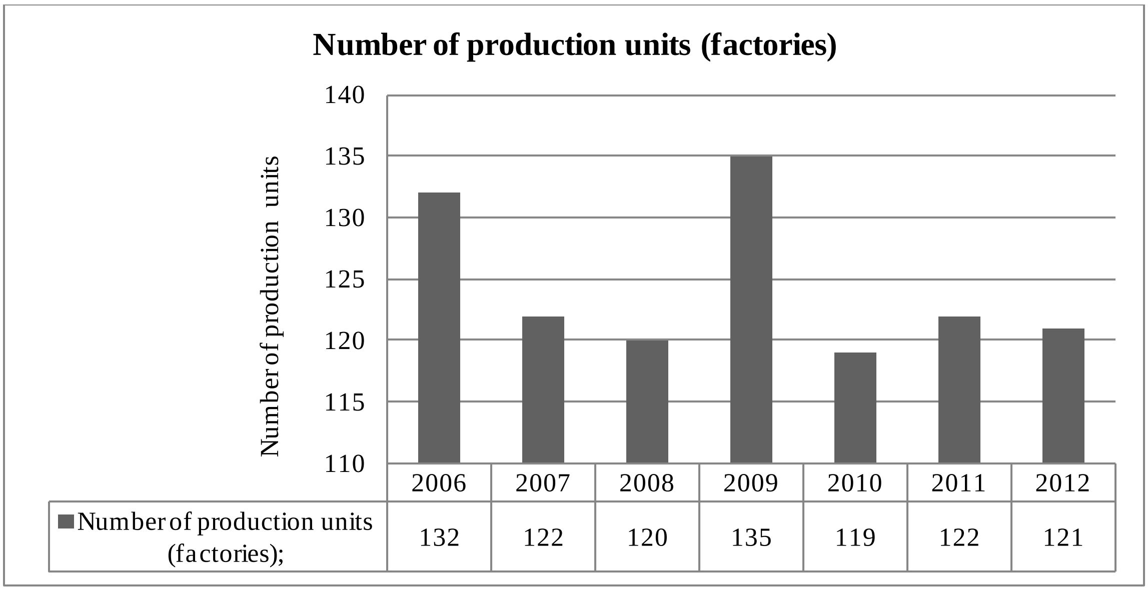


Figure 4.7: Number of production units (factories)

3. **Precast concrete production;** as show in figure 4.8, in 2006 production was around 17 million tonnes, in 2007 production increased by 2.9 million tonnes. This can be attributed to increase in the number of companies that provided data from 19 companies in 2006 to 25 companies in 2007. In 2008, the number of companies that provided data was 26 with 120 factories in operation, however, as shown in figure 4.8, production drastically fell from 19.9 million tonnes in 2007 to 11.99 million tonnes in 2008 (loss of 7.91 million tonnes). This can also be attributed to the contraction of the industry due to recession and two major precast manufacturers didn't provide data for the year. The number of companies didn't increase much from 2008 to 2011, despite these, production still dropped from 11 million tonnes in 2008 to 10.03 million tonnes in 2012 with a total of 36 companies.

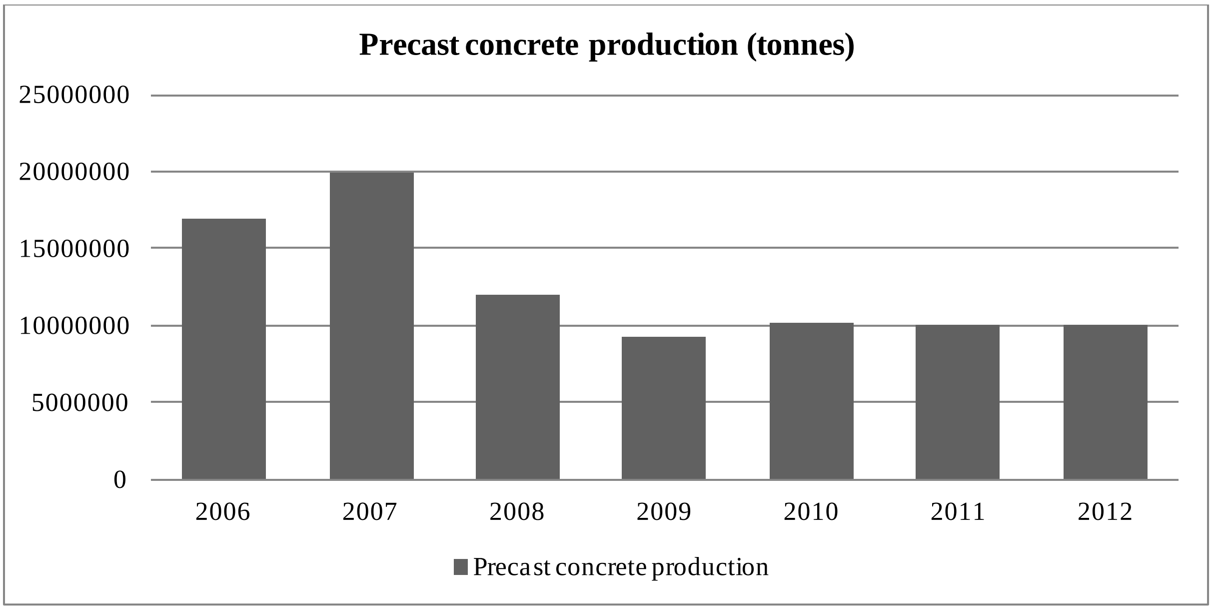


Figure 4.8: Precast concrete production (i.e. British Precast members that submitted KPI data)

4. **Number of employees;** in 2006, 8,309 people were reported employed in the industry, the number increased to 9, 735 in 2007 which was an increase of 1426 employees. However, from 2007 to 2011 there was a sharp decline in numbers to 5, 785 employees. There was no increase in employees till 2012 was stands at 6585 employees.

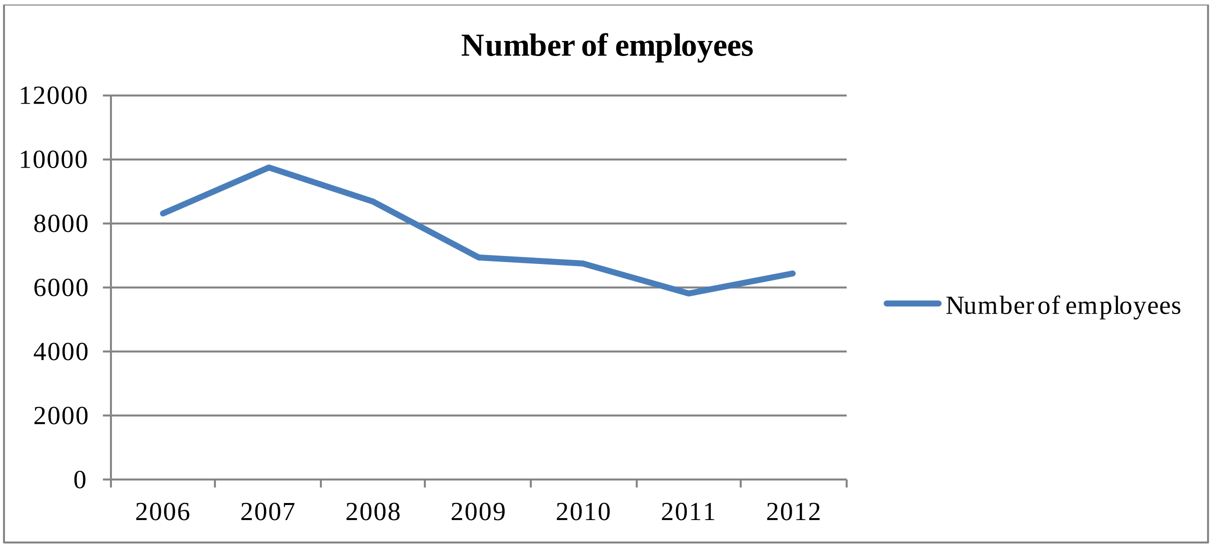


Figure 4.9: Number of precast concrete employees for companies that submitted KPI data

5. **Energy used per tonne of concrete produced (kWh/t);** general emery is used in precast concrete production sites for curing and general use office/ factory use for

heating, ventilation and lighting. In 2006 the figure was 54.9 kWh/t, this dropped to 52.9 kWh/t in 2007 despite the increase in number of companies that provided data. This may be attributed to updates in data and improvements in terms of accuracy of data collection, energy improvements in terms of machinery and equipment at factories, and/ or other energy management strategies employed. Despite a record drop in production, there was energy use increased from 2008 to 2010 i.e. 62.7 kWh/t, 67.9 kWh/t, 71.4 kWh/t respectively. This shows a pattern and certainly may be attributed to loss of member companies with higher energy efficient manufacturing and energy management systems in place.

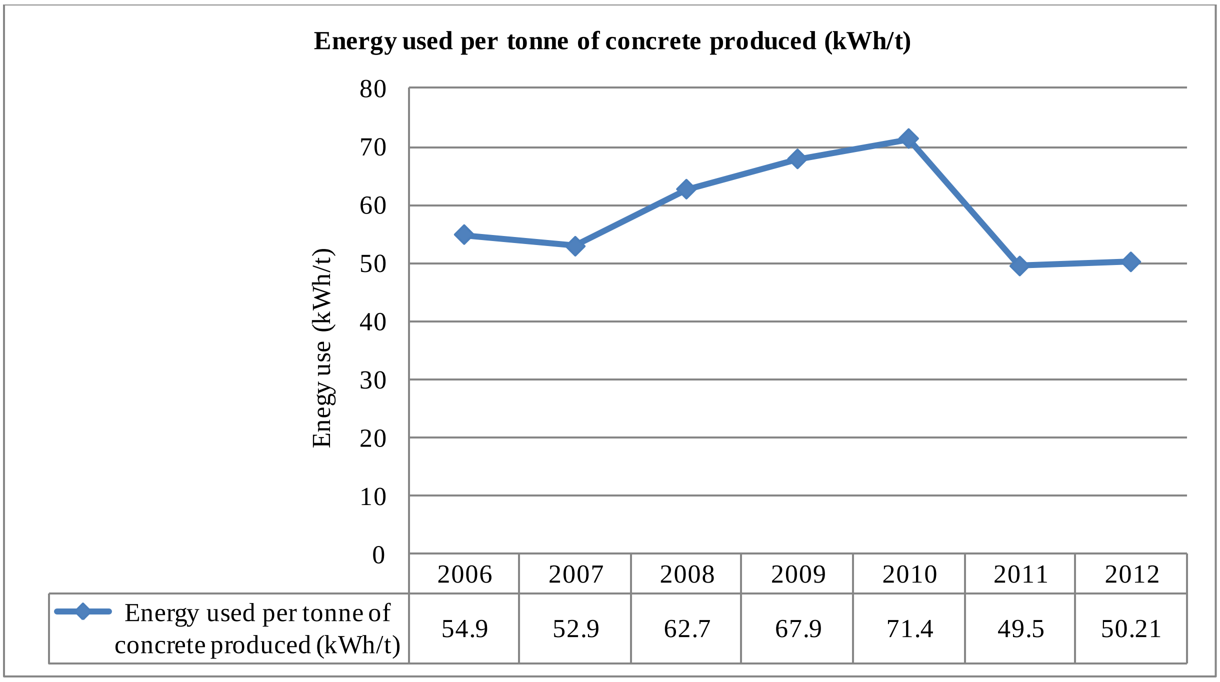


Figure 4.10: Energy used per tonne of concrete produced (kWh/t) from 2006 to 2012

6. **Litres of water used per tonne of concrete produced (l/t);** generally, concrete requires water for mixing and hydration purpose. In terms of water use, the highest recorded water use was in 2008 which was 169.6 litres per tonne of concrete produced. The year 2006 recorded 163 litres per tonne of concrete produced and a decrease was recorded in 2007 by 7 litres per tonne of concrete produced. Between 2008 and 2009 there was a reduction in water use of 22.9 litres per tonne of concrete produced, and in the following year, 2010, there was a massive reduction of 47.3 litres per tonne of concrete produced. Though the data in the year does not include water from other

sources such as recycling and rain water harvesting are not included in the figure; Figure only shows water from mains water supply.

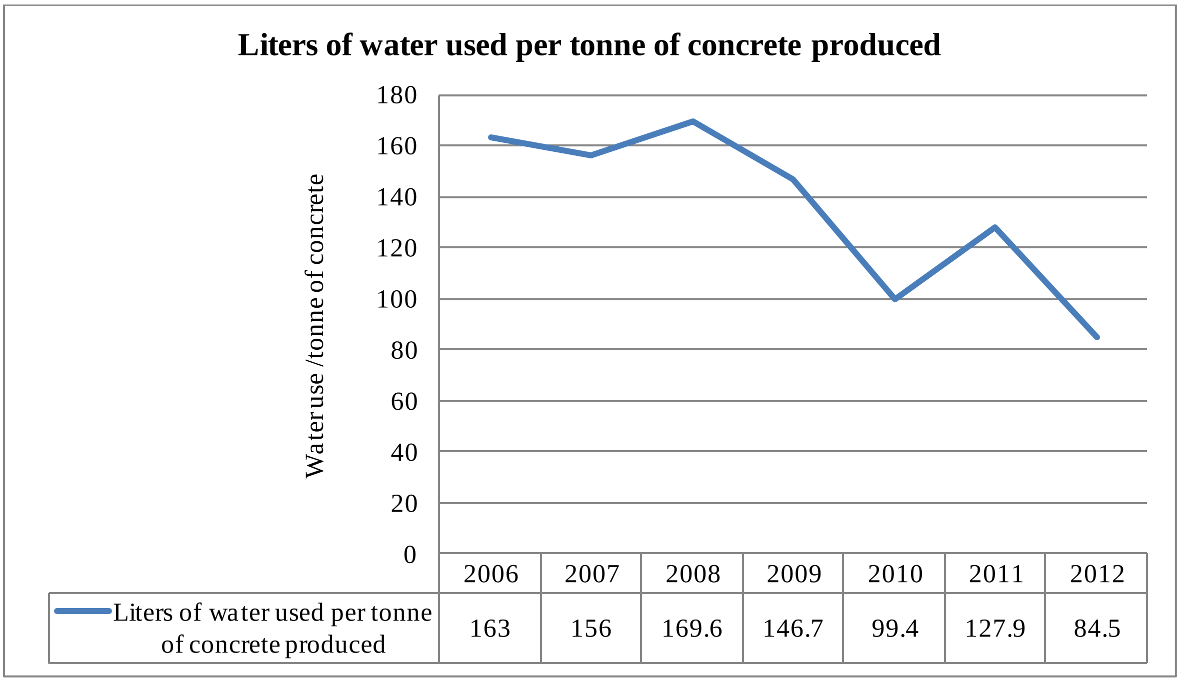
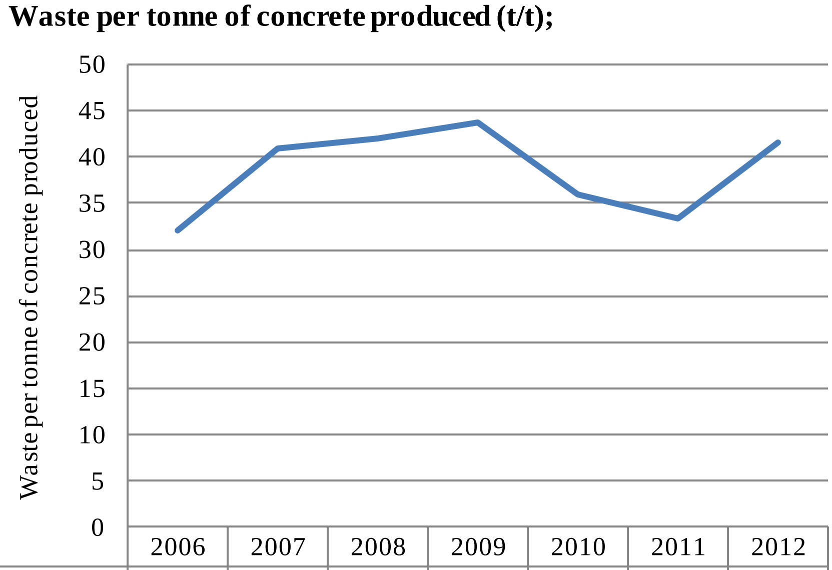


Figure 4.11: Litres of water used per tonne of concrete produced from 2006 to 2012

7. **Waste per tonne of concrete produced (t/t);** generally concrete is a very good material with recycling properties and advantages. In the 2006, waste per tonne of concrete produced (t/t) was 32t/t. There was an increase of 9t/t in the following year 2007 to 41t/t. The subsequent years 2008 and 2009 recorded increases to 42.1t/t and 43.7 respectively. However, 2010 and 2011 witnessed decreases to 36 t/t and 33.3t/t respectively.



	2006	2007	2008	2009	2010	2011	2012
Waste per tonne of concrete produced (t/t);	32	41	42.1	43.7	36	33.3	41.64

Figure 4.12: Waste per tonne of concrete produced (t/t)

8. **Cementitious materials used per tonne of concrete produced (t/t);** this has an uneven pattern, in 2006, cementitious materials used per tonne of concrete produced (t/t) was 0.140, it increase to 0.175 t/t in 2007 and decreased to 0.130 in 2008. From 2009 to 2010 the figure stayed the same at 0.141t/t. In 20011 the figure increased to 0.147 t/t and reduced to 0.142t/t in 2012.

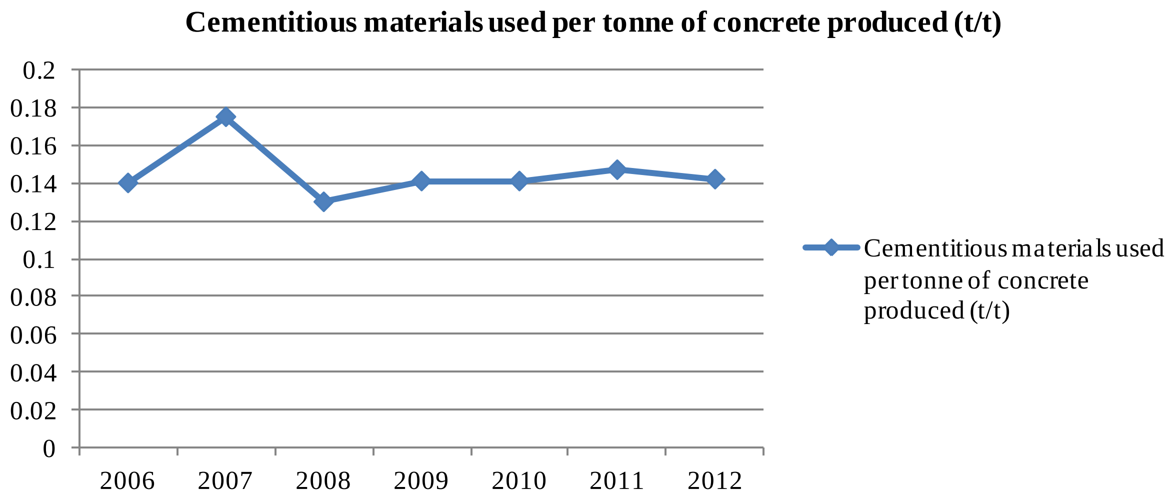


Figure 4.13: Cementitious materials used per tonne of concrete produced (t/t)

Looking at the KPI statistics of companies that submitted data from 2006 to 20012, there seems to be a clear representation of facts that precast concrete:

- Production has decreased from 17 million tonnes in 2006 to 10.03 million tonnes that is 6.97 million tonnes reduction;
- The number of companies providing data has increased from 19 in 2006 to 36 in 2012;
- The number of employees has also reduced from 8, 309 in 2006 to 6, 858 in 2012 which is 1451 reduction. The all-time highest number of employees was 9, 735 in 2007;
- As a major user of cement, cementitious material, energy, water and net producer of waste (from aggregates, used concrete and production), figures suggest that energy use has consistently been high. Water use has also been high from 2006 to 2011, though, presently it has reduced to 84.5 in 2012 which can still be a concern.

All the above points have provided the basis to identify areas that needs the industry's attention for mitigation and adaptation. The precast concrete industry's 2020 targets also contain some of the identified areas.

Table 4.4: A summary of BPCF member companies' Key Performance Indicator data from 2006-2012 (After Holton, 2009, British Precast, 2010; 2014 and Aliyu *et al.*, 2012).

Year	Number of companies that provided data	Number of production units (factories)	BPCF members' reported production (tonnes)	Number of employees	Energy used per tonne of concrete produced (kWh/t)	Litres of water used per tonne of concrete produced (l/t)	Waste per tonne of concrete produced (t/t)
2006	19	132	17,000,000	8,309	54.9	163	32
2007	25	122	19,900,000	9,735	52.9	156	41
2008	26	120	11,990,000	8,681	62.7	169.6	42.1
2009	27	135	9,300,000	6,902	67.9	146.7	43.7
2010	26	119	10,200,000	6,732	71.4	99.4*	36.0
2011	24	122	10, 100,000	5, 785	49.5	127.9	33.3
2012	36	121	10,030,000	6, 585	50.21	84.5	41.64

Year	Production covered by ISO 9001 (tonnes)	Percentage of BPCF members reported Production (per cent)	Cementitious materials used per tonne of concrete produced (t/t)	ISO 14000 series or EMAS (Production coverage in tonnes)	ISO 14000 series or EMAS (Percentage of production)	Production covered by OHSAS 18001 Health and Safety (tonnes)	Production covered by OHSAS 18001 Health and Safety (per cent)	Percentage covered by employees who had formal training (per cent)
2006	14,000, 000	81.5	0.140	12,900,000	75	4,400,000	25	85
2007	14,300, 000	80.0	0.175	14,500,000	81	4,800,000	26.7	73
2008	10,100, 000	84.5	0.130	10,100,000	85	3,500,000	25.4	94.1
2009	8,200,000	87.7	0.141	7,400,000	79.1	2,700,000	39.1	94.7
2010	9,500, 000	93.1	0.141	9,220,000	90.3	4,900,000	48.4	98.5
2011	9,450, 000	93.4	0.147	9,250, 000	91.9	6,340,000	62.74	99.8
2012	9,100, 000	96.1	0.142	8,860, 000	93.2	6.340,000	56.7	98.51

* Caveat: Water from other sources such as recycling and rain water harvesting are not included in the figure; Figure only shows water from mains water supply.

4.4.3. 'HOT-SPOTS' IN THE KPI DATA.

Based on the analysis of the KPI data and the literature review carried out in this chapter, it was possible to identify a few specific 'hot-spots' that are rightfully of particular concern to the precast industry, as described below.

Materials: Material extraction is one of the major sources of grave environmental, social and impacts and concern to the precast concrete industry. The production and use of cement, extraction of aggregates e.t.c. are major sources of impacts upstream the supply chain (CSI, 2012; Bijen, 2002 and Sakai, 2008). According to Mehata and Monteiro (2014), ordinary concrete consists of 80 percent aggregate, 12 percent cement and 8 percent water by mass. Precast concrete products are produced from several constituent ingredients, i.e. cement, aggregates, water, admixtures, additives and pigments (Levitt, 2007) and although the range of impacts arise from the extraction, processing, use and disposal of these ingredients, cement manufacturing and processing dominates the environmental impact of all concrete products. Yet cement impacts are 'inherited' impacts because they result from upstream manufacture, so are not within the gift of the precast industry to address. Hence, the use of non-Portland cement based binders (CEM II) has become a commonly accepted method used by product manufacturers to reduce the embodied 'inheritance' of such impacts. From table 4.4, statistics shows that cementitious materials used per tonne of concrete produced (t/t) on average between 2006 to 2012 has been 0.165 t/t this is very high and that is the reason why materials is classified as a 'hot-spot' for the industry.

Energy and climate change: Within the EU, the European Commission made a commitment for the reduction of GHG emissions by 20% by 2020 compared to 1990 levels (IEA, 2010), but the UK concrete industry is a major consumer of fossil fuel. The primary sources of energy are gas, electricity, gas oil or diesel. Data from the industry shows that energy used per tonne of concrete produced (kWh/t) has been fluctuating from 2006 to 2012. As shown in Table 4.4 and Figure 4.10, the lowest recorded energy use was in 2011 at 49.5kWh per tonne of production output and the highest being 71.4 kWh per tonne. The precast concrete industry energy usage stands at 62.7 kWh/t in 2008 and equates to 17kg of CO_2 per tonne of concrete produced. Currently the target is to reduce the overall kWh/t of energy use in production and the CO_2 in production both by 10%; but adapting to climate change requires information, equipment and infrastructure (Stern, 2008), so this is not a simple task.

Water management: Water is one of the main ingredients of concrete: mains water consumption as a proportion of production output (litres/tonne) was between 86.1 -80.6 litres from 2008 (Sustainable Concrete, 2014), much of which is utilised for hydration and hence strength gain. Between 2006 to 2009, water usage in the precast concrete industry data shows approximately between 146.7 to 169.6 litres/ t (see Table 4.4 and Figure 4.11). Other uses of water in concrete production include hydration, mixing, washing, cleaning, batching and consumption by employees. Data on mains water usage/consumption in the concrete industry was 86 litres/tonne (CISCF, 2008), whereas the precast concrete industry's main water usage per tonne of concrete is up to 183 litres (British Precast, 2010). These figures show a clear need for improved water management (see Figure 4.11). Measures such as increased monitoring, recycling and treatment, rain water harvesting, and the use of water-reducing admixtures are methods that can help toward better water management in the industry.

Waste management:

On average, from 2006-2012, the industry produced between 32 -43.7 kg of waste per tonne of production (see Figure 4.12 and Table 4.1). In 2008, of the 42kg of waste produced per tonne in the precast industry, 49% was recycled off-site, 36% was recycled on-site and about 15% went to landfill. The precast concrete industry uses more waste that what it produces. "A tonne of precast product uses 218 kilogrammes of secondary materials and by-products and produces only 6 kilogrammes of waste that goes to landfill" (Sustainable Concrete, 2014). Concrete buildings can be designed with less finishes, reducing the associated material waste.

4.4.4. SUMMARY

So, the major environmental impacts associated with materials use, energy consumption, water and waste management are key to the precast concrete industry's efforts to improve its sustainability performance. This is entirely congruent with the drivers that propelled other sectors to utilise PS as a mechanism to manage and reduce environmental impacts. Like other sectors, the precast industry must also do this within the context of a product life-cycle management, so the tools that need to be implemented within a PS framework do need to address issues of shared responsibility, differing stakeholder values and the difficult issue of 'inherited' impacts. For these reasons, the next section explains how PS was interrogated for future use in the precast concrete industry context.

4.5 WP4: KEY COMPONENTS OF PS FOR THE PRECAST CONCRETE INDUSTRY

The aim of this WP was to collect views from manufacturers within the UK precast concrete industry, to understand their level of awareness and understanding of PS and broadly assess the potential for its successful, future implementation. The specific objectives of this WP (in the context of the UK precast concrete industry) were to:

- define and depict an industry-specific interpretation of PS;
- identify drivers and barriers to implementing a PS scheme; and
- identify any key conceptual and structural components and enabling mechanisms for doing so.

The outcomes from this WP are reported fully in Paper 3 (Appendix C).

4.5.1 RESEARCH APPROACH

Based on the evidence from a comprehensive review of literature and industry reports, factory visits and a review of industry sustainability KPI data, the research objectives were translated into a number of research questions, suitable for use in a social survey and/or personal interviews with selected UK precast concrete manufacturers. The initial set of questions (including a range of Likert scale, closed-ended and open-ended questions) were tested through a pilot study with two companies. Following the pilot exercise, a few more questions were added to enhance the quality and depth of the research instrument and ease completion by the subject. At this point it was also confirmed that the data collection would comprise two sets of data, firstly using a self-completion questionnaire and secondly using a semi-structured personal interview schedule.

The self-completion questionnaire can be found in Appendix E. For questions using a Likert scale, a weighting factor was applied in order to attribute greater value to the higher scores and so acquire a better understanding of the pattern of responses. A weighting factor was applied as shown in Table 4.6. So, for example, with a total of 12 respondents, the maximum possible score for any such question would be 12 'votes' for 'Extremely important', which is weighted at 5; hence scores are shown out of 60. This method provides a proxy 'approval rating' for each option shown as a percentage value for ease of comparison.

Table 4.6: Weighting factors used in analysis of Likert questions

Scoring scale (Likert)	1 = Not important	2 = Fairly important	3 = Important	4 = Strongly important	5 = Extremely important
Weighting factor	1	2	3	4	5

The semi-structured interview template can be found in Appendix E. The questions were designed to probe answers from the self-completion questionnaire for greater depth. For example, in the questionnaire, a Likert scale question was asked on the extent to which current Life-Cycle Management (LCM) methods are suitable and sustainable. Then, follow-up questions were asked during the interviews, e.g. on the policy or system put in place to mitigate life-cycle impacts; balancing of sustainability requirements; and steps taken by companies on embodied or inherited impacts upstream and downstream. Where appropriate, interviewees were also shown the PS models developed in WP2 to help them provide responses. The rationale for the selection of companies for the research was that the sample should:

1. represent the full range of precast product types manufactured in the UK;
2. include a range of small, medium and large size companies, by turnover and head count; and
3. account for the majority of the UK precast industry's total output, by volume and value.

Based on the criteria above, 16 companies within the UK precast concrete industry were identified and invited to take part in the research between February-April 2011. These companies collectively accounted for about two-thirds of the precast concrete industry production tonnage (based on 2010 figures), so their staff should arguably have been able to represent the significant majority of the industry in terms of status, experience, market share and expertise. Each was sent a formal email which was followed up by a phone call to reassure participants and clarify details. 12 companies opted to take part and each identified a suitable person to act as their representative – these individuals were sent a copy of the self-completion questionnaire in advance of the interviews. The 12 semi-structured interviews were conducted either within the premises of the respective companies that took part in the survey or at other convenient locations.

4.5.2 RESULTS AND ANALYSIS

This section presents some of the key findings from the survey and interviews.

Profile of the respondents' companies

The 12 UK precast concrete companies which took part in the research produce in excess of over 6.7 million tonnes of precast concrete products, and represent the full range of precast products manufactured in the UK. Based on the EU definition of business sizes[2], three companies could be classed as large (based on both turnover and head count), while eight could be classed as medium-sized and one as a small-sized company (hence nine can be classed as SMEs). Turnover is not reproduced here owing to commercial sensitivities, but Table 4.7 does show the respondent companies classified by headcount against the EU definition.

Table 4.7: Categorisation of respondent companies' size.

Categorisation of companies based on the EU SME Definition		
Company category	Staff headcount (number of persons expressed in annual work units)	Number of companies
Large-sized	Over 250	3
Medium-sized	< 250	8
Small-sized	< 50	1
Micro	< 10	0
Total		12

The roles of individual respondents ranged from company director, environment advisor/ leader, head of sustainability, head of HSE, HSE manager, process systems manager and precast design manager; level of seniority ranged from director to middle-management level staff.

Current methods for the 'life cycle management' (LCM) in precast concrete manufacturing

This question was aimed at understanding how life-cycle management (LCM) methods are currently used by precast concrete manufacturers. Table 4.8 shows that recycling is perceived as the most commonly used approach, with life-cycle assessment also seen as an important tool. Indeed, obtaining an independent third-party recognised LCA assessment

[2]The category of micro-, small- and medium-sized enterprises (SMEs) is made up of enterprises which employ fewer than 250 persons and which have an annual turnover not exceeding 50 million euro, and/or an annual balance sheet total not exceeding 43 million euro (extract from Article 2 of the Annex of Recommendation 2003/361/EC).

for all or part of their products and services was also being considered by eight of the respondents (including all the SMEs). Two SMEs and one non-SME had already certified LCAs (for all landscaping products and pipes products), which had helped them in data capture on key hotspots and cold spots within the manufacturing process. This level of participation is similar to that found by Horne *et al.*, (2009:19), who examined uptake of LCA in the brick and tile industry. Here, cost was cited as a barrier to wider participation as was the level of understanding of LCA amongst clients. This also concurs with Ding (2008) that conducting an LCA can be costly.

Table 4.8: Weighted scores and ranked list of life-cycle management methods.

Life-cycle methods	Weighted score	Percentage 'approval rating'	Rank
Recycling	46/60	77%	1
Life cycle assessment	39/60	65%	2=
Life cycle costing	39/60	65%	2=
Material recovery	33/60	55%	4
Reuse	32/60	55%	5
Material collection	27/60	45%	6
Take back	20/60	33%	7
Other (raw material supply was cited by a single respondent)	4/60	6%	8

Apportioning sustainability impacts through stakeholder responsibility

Respondents were asked about the extent to which designers, suppliers, contractors, clients, manufacturers, government, users or others have a stake in the sustainability impacts of the precast concrete industry (from design, production, construction/installation, use, maintenance and end-of-life). This is a critical gap in the construction literature; Lewis (2005) and Adams (2011) argue that stakeholder involvement and share is a vital component in successful PS schemes; yet surely this should be reflective of relative impacts. Figure 4.14 shows that there is a perceived asymmetry (with manufacturers feeling that they and designers should take on the lion's share of impacts), which should be taken into account in the development of a PS scheme for precast concrete. One respondent noted:

> *"Our company is aligning its business objectives with stakeholder expectations, which are ever growing. The UK precast concrete industry presents a significant and appropriate stakeholder view. The KPIs for energy, waste, materials use, training, water use, community, and so on, are driving our business processes to*

make improvements and lessen the environmental impacts of both our products and business". (Large precast concrete block and paving manufacturer).

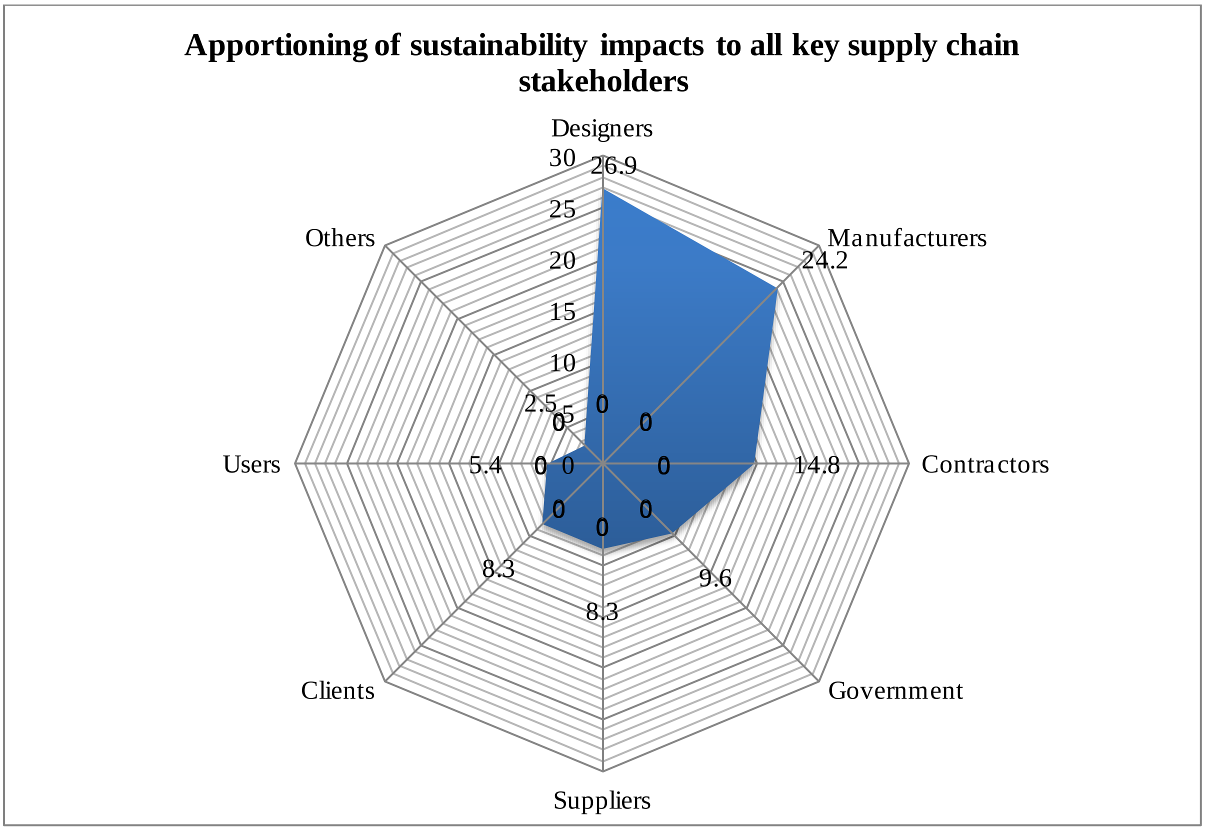


Figure 4.14: Asymmetry in stakeholder perceived impacts in the precast concrete supply-chain.

However, environmental assesments from LCA studies from literature contradicts the position of the manufacturers that they and the designers are responsible for the impacts of concrete. Studies suggest that cement as a constituent ingredient of concrete is the major source of carbon emissions. Malhotra (1988) and Swamy (1998) suggest that cement production is highly energy intensive in nature and consumes 4 – 7 MJ of fossil fuel energy per kg . During the production of Portland cement, 1 tonne of cement requires 1.5 tonnes of raw material and for each tonne of portland cement, a tonne of CO_2 is emitted (Elchalakania, 2014: 10). Mehata and Monteiro (2014) proposition is that ordinary concrete consist of 80 percent aggregate, 12 percent cement and 8 percent water by mass.

Sustainability management – decomposition into key issues

Based on the precast concrete industry's KPI categories and the interpretive models for PS, the research also probed sustainability management (around specific environmental, social and economic aspects). The results generally depicted high approval ratings, which confirms the relevance of certain issues and corroborates their inclusion in the industry's KPI dataset discussed earlier. One respondent said:

> *"The sustainability initiatives of the UK precast concrete industry are largely following wider trends within the market. In particular the increasing need for hard metrics to show a demonstrable understanding and reduction in resource use allied to ethics/ responsible product sourcing. We're monitoring better and now doing something with the data in particular; water, waste, electric and fuel usage – it's helping us drive down costs".* (Medium-sized concrete landscaping and building products manufacturer).

Environmental issues: Here, respondents were asked about the value of environmental management systems (EMS), e.g. working to BS 8555: 2003 or ISO 14001: 2006, because literature clearly identifies the value of EMS as a platform for sustainability improvements within manufacturing companies (e.g. Holton *et al.,* 2010). A further set of specific environmental impacts were listed and respondents were asked to rank these on the Likert scale (see Table 4.9). Environmental Management Systems are considered of utmost importance, followed by Waste Minimisation and Embodied impacts (e.g. from cement).

Table 4.9: Weighted scores and ranked list of environmental aspects.

Environmental issues management	Weighted score	Percentage 'approval rating'	Rank
Environmental management systems	55/60	92%	1
Waste minimisation	45/60	75%	2=
Embodied impacts[2]	45/60	75%	2=
Emissions (CO_2 from production and transport)	42/60	70%	4
Site stewardship and biodiversity	41/60	68%	5
Emissions (excluding CO_2)	38/60	63%	6
Mains water consumption	37/60	62%	7=
Energy efficiency	37/60	62%	7=

***Caveat -** *the definition of some terms used in table 4.9 are given as:*

Embodied carbon: *"is the Carbon Dioxide (CO2) or greenhouse gas (GHG) emissions associated with the manufacture and use of a product or service. For construction products this means the CO2 or GHG emission associated with extraction, manufacturing, transporting,* *installing, maintaining and disposing of construction materials and products*" (Anderson and Thornbark, 2012: 28).

Emissions: refer to the carbon emissions from production to transport (Cradle-to-gate emissions).

Energy efficiency *According to the International Energy Agency (IEA) "is a way of managing and restraining the growth in energy consumption. Something is more energy efficient if it delivers more services for the same energy input, or the same services for less energy input" (IEA, 2014).*

Social issues: the social dimension of sustainability is less well-understood and represented within precast manufacturing, but rather tends to home in on a few serious issues, such as health and safety (for which there are sector and national targets), workforce and the local general public/neighbours. Unlike the on-site-based construction industry (which has the Considerate Constructors Scheme), no overarching scheme exists against which social achievements can be measured; but Table 4.10 shows that approval ratings are generally high, indicating the respondents' support for these issues.

Table 4.10: Weighted scores and ranked list of social aspects.

Social issues management	Weighted score	Percentage 'approval rating'	Rank
Health and safety	54/60	90%	1
Respect for people	45/60	75%	2
Employment and skills	44/60	73%	3
Local communities	43/60	72%	4=
Employee satisfaction	43/60	72%	4=

Economic issues: Respondents were specifically asked questions on productivity, taxes paid, contracts awarded and executed, and how these affect the achievement of sustainability goals within their respective companies. The cost of all goods, material and services was ranked first (see Table 4.11), followed by taxes paid.

Table 4.11: Weighted scores and ranked list of economic aspects.

Economic issues management	Weighted score	Percentage 'approval rating'	Rank
Costs of all goods, materials and services	46/60	77%	1
Taxes paid	45/60	75%	2
Penalties and liabilities	44/60	73%	3
Annual profits after tax/revenues	44/60	73%	3=
Productivity	43/60	72%	5=
Contracts awarded and executed	43/60	72%	5=

So, the outcome of the question was analysed by having three groups each representing environment, social and economic issues.

For the environment; the top issues out of the eight where Environmental Management system with 92% approval rating was ranked as the first. Waste minimisation and embodied impacts had a tie with both having a 75% being (2 and 3) and emissions (CO2 from production to transport got 70% approval. All the other four environmental issues had more than 60 percent each).

For social issues; health and safety had a 90% approval rating, followed by respect for people which stands at 75 percent. The other three social issues had 73 percent, 72 percent and 72 percent.

Economic issues, have the cost of goods, material and services with an approval rating of 77% and taking the first place and taxes paid is number two. There was a tie on the third and fourth place with 73 percent.

It is obvious that from the three groups, most issues received quite a high approval rating - the minimum was 62% (energy efficiency), the highest, with an approval rating of 92%, was environmental management systems, but concerns around health and safety (90%) were also clearly at the forefront of the respondents' minds.

Understanding change in the precast concrete industry

The respondents were asked to identify one main driver for change within the industry, as shown in Figure 4.15. The number is too small to draw meaningful conclusions; rather it is the balance/range which is of interest here.

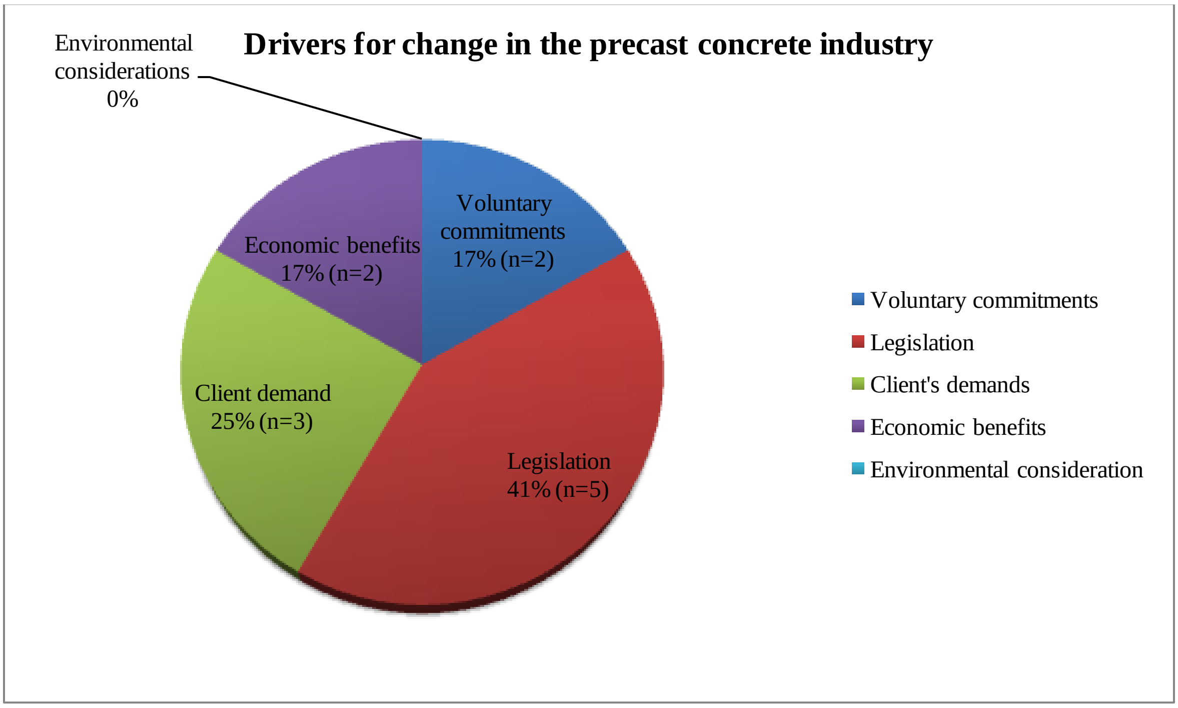


Figure 4.15: Drivers for change in the precast concrete industry.

Of the 12 companies that responded, five cited 'legislation' as the most effective driver for initiating change and three selected 'client demand'. Interestingly, four SMEs chose 'Legislation' – clearly these organisations tend to wait 'until they have to' to instigate change, whereas larger companies may have the resources to 'get ahead of the curve' and act on a voluntary basis. Three respondents said that combinations of drivers were more likely to make change happen. The respondents were also asked to state which barriers they believed impeded change in the industry, as shown in Figure 4.16.

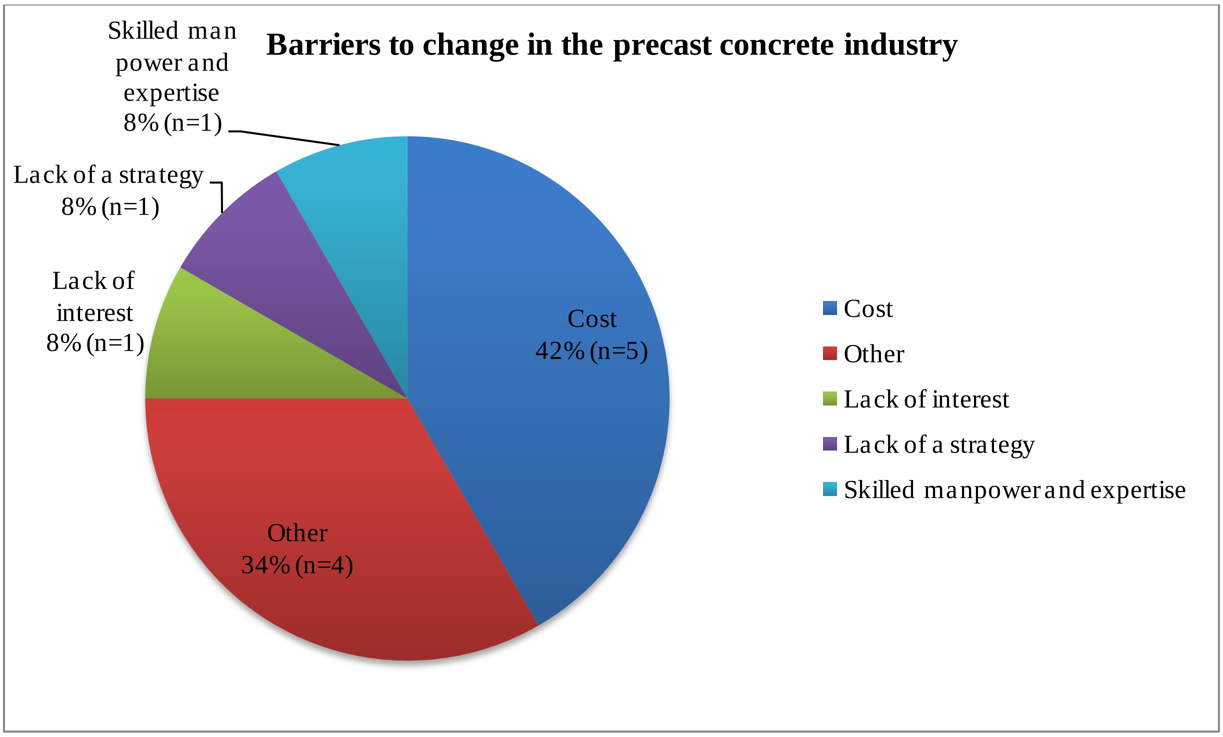


Figure 4.16: Barriers to change in the precast concrete industry

Under the other category which has 34 percent, four companies (n=4) cited the following as their barriers to changes which are:

- Market continuing to decline, this reduces margins, which reduces profit and money for re-investment;
- Economic climate;
- Lack of legislation and clear direction on policy from UK government; and,
- The traditional building method with extensive on site build time.

Industry perceptions and potential reactions to PS

The respondents were asked about their understanding of what PS meant, in the context of the precast concrete industry. They were shown the interpretive generic models from a selection of existing PS schemes and asked to reflect on these, in an open-ended discussion. Their answers suggested that PS, as applied to the precast industry, was essentially grounded within three overarching themes:

- responsible/ethical sourcing of products and materials;
- stakeholder responsibility along the chain of custody of the product; and
- the management of life-cycle impacts.

Business case

Furthermore, the business case for implementing any change in the precast industry may need to be based on there being a positive outcome measured against a range of factors, which would probably include evidence of:

- clear commercial benefits to the business, either increased revenue or reductions in costs, or both;
- demand from the market, via clients/customers;
- demand from the sector, industry or policy-makers; and/or,
- legislation being planned or already in place.

All of which concurs with findings from Kleindorfer *et al.*, (2005), Scheer (2006) and Seuring and Müller (2008).

Summary

This section highlights that a number of initiatives associated with PS have been carried out by individual member companies of BPCF but are not understood to be part of PS; the asymmetry in Figure 4.7 supports the need for the industry to adopt a PS approach as multiple stakeholders are perceived as having an impact regarding the impacts of the industry. The major stakeholders identified are clients, designers and manufacturers. It is obvious that from all the PS schemes analysed in Chapter 2, there is a powerful set of barriers present within the precast concrete industry which commonly prevent the companies from enacting change.

4.6 WP5 - DEVELOPMENT OF A PS FRAMEWORK FOR THE PRECAST INDUSTRY BASED ON EPD

This work package explored the potential of an industry approach to the communication and reporting of PS and life-cycle management information through the development and operation of a precast concrete sector EPD scheme. It explores how a possible scheme format could look, and assesses the main challenges and factors associated with the implementation of a successful EPD scheme.

A literature review on EPD was undertaken and presented in Chapter Two. Further to the review, an industry focus group was conducted with six precast concrete manufacturing companies which identified a number of factors and challenges associated with the nature of the industry, the political environment, and the supply chain. Two interviews were carried out afterwards with sustainability experts within the industry to understand some of the key requirements of a precast concrete EPD scheme and identify the opportunities, challenges, threats and their associated risks, and short, immediate and long-term benefits of EPD.

Legislation was agreed to be the key driver towards EPD development within the industry. All interviewees agree that; the short term benefits of EPD to the industry are becoming EPD complaint and the industry body (i.e. BPCF) should lead its development. The approach to the EPD developmental stages was generally also agreed to be a cradle-to-gate methodology and all British Precast member companies should be the major stakeholders. However, within BS EN 15804, options have been given for different life cycle stages from product stage to end of life (see page 126, Figure 5.5). With regards to implementation and challenges, all interviewees agree that the EPD content should be compliant with all the relevant standards (see Section 4.6.2) and the governance structure should consist of a scheme operator and third party verification component; and the key challenge to EPD implementation are the issues of cost, training and other resources. All of the data collected through the focus group and interviews were used to inform the development of an EPD framework for the industry, which is the focus for this WP.

4.6.1. DEVELOPING AN EPD FRAMEWORK

Zakrisson *et al.* (2008) suggested a five-step approach to EPD development:

a. making a simplified or streamlined life-cycle assessment, LCA, to identify the most significant environmental aspects and impacts of the product;
b. formulation of product category rules together with interested parties;
c. making a detailed life-cycle assessment to validate and supplement the results of the initial assessment;
d. drafting of EPD; and
e. independent verification of the life-cycle assessment and the EPD.

Yet ISO 14025 clearly specifies the two methodologies to be followed for the development of Type III environmental declarations. Figure 4.17 shows option A and option B. Both options require a LCA study, which includes goal and scope definition, inventory analysis (LCI), and interpretation.

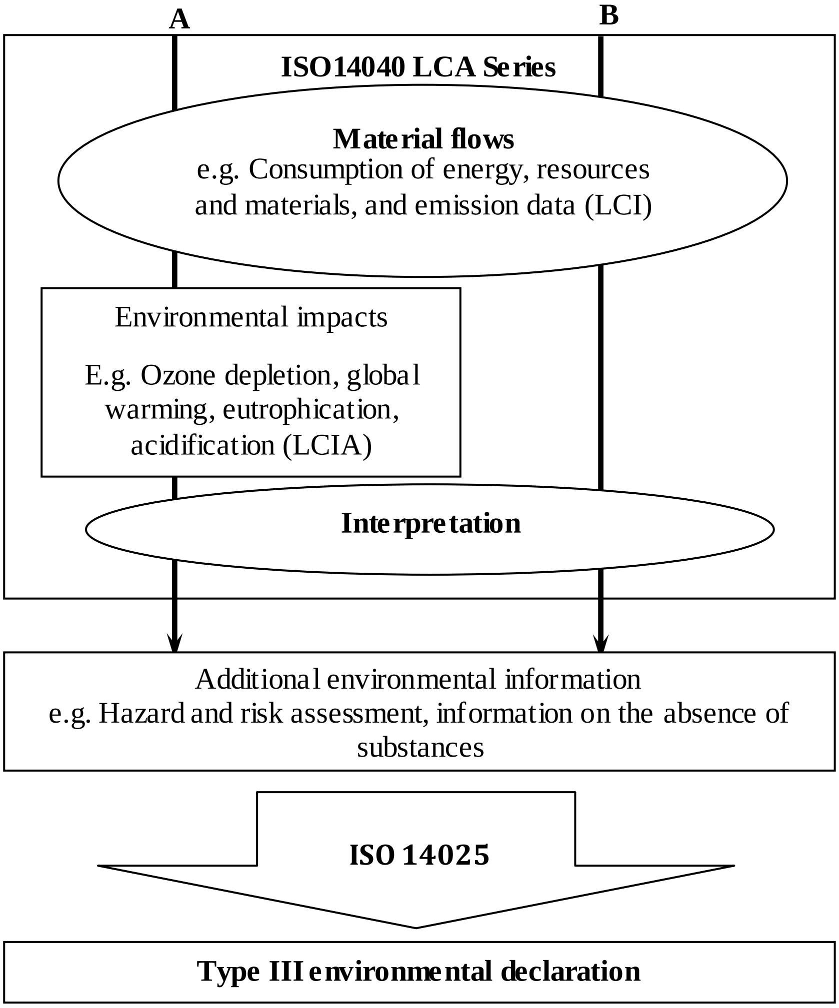


Figure 4.17 – Two different methodological options for Type III environmental declaration and programmes. Source: ISO 14025 (2010:12).

The major difference between the two options is that option A requires impact assessment (LCIA) while option B does not. Fet *et al.*, (2009) suggest there is potential to create an EPD specifically for construction materials without carrying out a Life-cycle Assessment (LCA). However, it should be made clear how and in what ways the EPD covers environmental impacts from raw material extraction to production. Within any EPD development, it is important to understand the following technical terms:

Product category: "Set of products that can fulfil equivalent functions" (Fet and Skaar, 2011:202; ISO 14025, 2010:3).

Product category rules (PCRS): ISO 14025 defines PCRs as "set of specific rules, requirements and guidelines for developing Type III environmental declarations for one or more product categories". Fet and Skaar (2011:202) explain that PCRs: *"Define the criteria for a specific product category and sets out the requirements that must be met when preparing an EPD for products under this category. The PCR aims to identify and define rules for the process of creating an EPD, to enable a comparison between products".*

TYPE I EPD: According to ISO 14024 (2001:1), the Type I environmental labelling programme is a: *"…Voluntary, multiple criteria-based third party programme that awards a licence which authorises the use of environmental labels on products indicating overall environmental preferability of a product within a particular product category based on life cycle considerations".*

TYPE II EPD: ISO 14021 (2001:2) explains that Type II environmental labelling is a *"self-declared environmental claim that is made, without independent third-party certification, by manufacturers, importers, distributors, retailers or anyone else likely to benefit from such a claim".* Type II environmental declarations are self-declared environmental claims where life cycle considerations are taken into account (ISO14021: ISO1999b).

TYPE III EPD: According to ISO 14025 (2010: iv), Type III environmental declarations present quantified environmental information on the life-cycle of a product to enable comparisons between products fulfilling the same function. A Type III EPD is a set of quantified environmental data consisting of pre-set categories of parameters based on Life-cycle Assessment (LCA) according to the ISO 14040 series of standards, with at least a minimum set of parameters for each product group (DG Environment, 2002).

4.7 DEVELOPING A PRECAST-SPECIFIC SCHEME

The UK precast concrete industry has an opportunity to develop an industry-wide approach to EPD that is compliant with all the relevant ISO and BS standards (e.g. ISO 14025, EN BS 15804, ISO 14044, CEN TC 350 etc.) related to EPD. The EPD scheme can be centralised and managed by the trade federation with third-party independent verifiers as PCR consultants. This will go a long way in positioning the industry to voluntarily market its products and green credentials in a more efficient and effective manner while also reducing its environmental footprints/impacts. In practice, the natural starting point of EPD development is the mandatory requirement for a product category (PC) to be developed for each of the products within the industry. The next step is to collect and/or produce appropriate LCA based on ISO 14044. A functional unit will be identified as the basis for unit usability measurement (e.g. m^2 for concrete slabs, roofing tiles, etc.) and as a basis on which direct comparison of similar or different products could be made (identified as 'Functional Equivalence'). The EPD can be owned and managed by manufacturing companies or their trade federations (e.g. BPCF), while the PCR can be owned by an independent third party in accordance with international standards (e.g. ISO14025, BS EN 15804). Validation and registration is required after this process.

4.7.1 STRUCTURE AND FUNCTIONAL PROCESS

The EPD framework developed will guide the industry towards setting up a dedicated precast concrete EPD scheme. The five key stages of the EPD scheme are as follows.

Stage A – Manufacturer registration and training workshop
Stage B – The use of a product category calculator, and the production of an unverified EPD from data that was collected and input into calculator.
Stage C – EPD verification
Stage D – EPD certification
Stage E – Release of EPD

These are presented in detail below and shown in Table 4.8 and Figure 4.11.

Stage A various stakeholders including; BPCF, precast concrete, member companies are involved in setting up an EPD steering group or committee. BPCF member companies will then decide on committee composition and their terms of reference. The steering group or committee is responsible in appointing qualified and competent consultants that will develop a product category document.

Stage B includes three important phases of product category document development. The first phase is defining the product category according to ISO 14025, second stage includes collection or production of LCA data and the third and final stage is the determination of product category rules by specifying all shared goals and rules for LCA and writing instructions on how to capture data for declaration. The main stakeholders in this stage are the consultants.

Stage C comprises establishing an EPD Training course, verification of the course by a consultant and approval by the steering group or committee**.** The main stakeholders involved in this stage are the consultants and the steering group or committee.

Stage D includes the appointment of a programme operator. The programme operator establishes the general EPD programme requirements, workshops, launching of the scheme and issue or presentation of certificates.

Stage E is the final stage of the framework and involves the certification and accreditation of the EPD scheme. The key stakeholders involved include; the certifiers e.g. United Kingdom Accreditation Service (UKAS) or International EPD system.

Table 4.12: Structure of the precast concrete industry EPD scheme

Stages	Preparation	EPD work stages				Stakeholders responsible	Stakeholder responsibility
		Steps	Category		Task description		
Stage A	BPCF member companies nominated representatives meet to decide on steering group or committee and team composition. Committee to decide or choose qualified and competent consultants for PCR document if necessary	Set up an EPD steering committee	A1		BPCF member companies nominated representatives meet to decide on steering group and team composition, committee mandate, terms of reference and operation and general running of committee		Steering Group or committee will oversee the general operation, development, and implementation and running of an effective and efficient EPD scheme for the UK precast concrete industry.
Stage B	Establish Product Category Rules (PCR) and PCR document	PCR should be developed according to ISO 14025 section 6.7	B1		Define product category; identification and classification of specific product or group of products that can fulfil specific functions		LCA based data for materials, parts and other inputs (as carried out based on B1 below) are the information modules and may represent the whole or a portion of the life cycle of those materials or parts.
				B1.1	Generate PCR document		PCR document should be in conformity with all relevant standards e.g; ISO 14025 and BS EN 15804.
				B1.2	Verification of PCR document		Independent verification body or consultants contacted by the programme operator must ensure that the verification procedure for review and independent verification are in conformity with ISO 14025 section 8 and BS EN 15804.
			B2		Collect or produce LCA Bank (Generic) e.g Ecoinvent, GABi database, INIES, European LCA data base e.t.c.		-
				B2.1	Establish LCA data bank or repository		LCA should be conducted by the relevant stakeholder (LCA researcher, Manager, consultant etc.). In the event were LCA are available and applicable, delegated or assigned stakeholder manages the LCA data.
				B2.2	Verify data within LCA data bank according to BS EN 15942 by an independent third party		
	Collect and / or produce appropriate LCA	LCA development or accessing LCA data bank for PCR document use	B3		Develop or produce LCA calculator		-
			B4		Verification of the LCA calculator		
			B5		Approve PCR document/ calculator and establish EPD format and content		Responsible stakeholder ensures that the PCR document produced is in conformity with ISO 14025 section 6.7
Stage C	Course approval, verification and establishing	-	C1		Approval of verifiers and experts, technical support and trainers of product manufacturers		-
				C1.1	Develop syllabus or course contents for training		-
				C1.2	Approve course contents, vetting and revisions		
				C1.3	Invitation of possible scheme verifiers		
				C1.4	Training and workshops		
			C2		Establish list of approved trainers		-
			C3		Verifiers to sign data protection charter		
Stage D	Programme operator assignment	-	D1		Appointment of EPD programme operator		Programme operator to carry out as the relevant tasks and responsibilities as outlined in section 6.3 of ISO 14025 and any other associated standards.
			D2		Establish general EPD programme requirements		This should be carried out by the relevant assigned individual(s) or consultant in accordance to section 6.4 of ISO 14025.
			D3		Workshop to approve EPD programme by interested parties		-
			D4				-
Stage E	Certification and accreditation of EPD	-	E1		Certification by the scheme operator Council and later Accreditation by UKAS/ EPD ®.		The independent consultant and the appointed verifier will be responsible for this task.

KEY: Programme operator | Certifier e.g UKAS or EPD® e.t.c | Consultant (independent) | Manufacturers | Steering committee | BPCF | Verifier

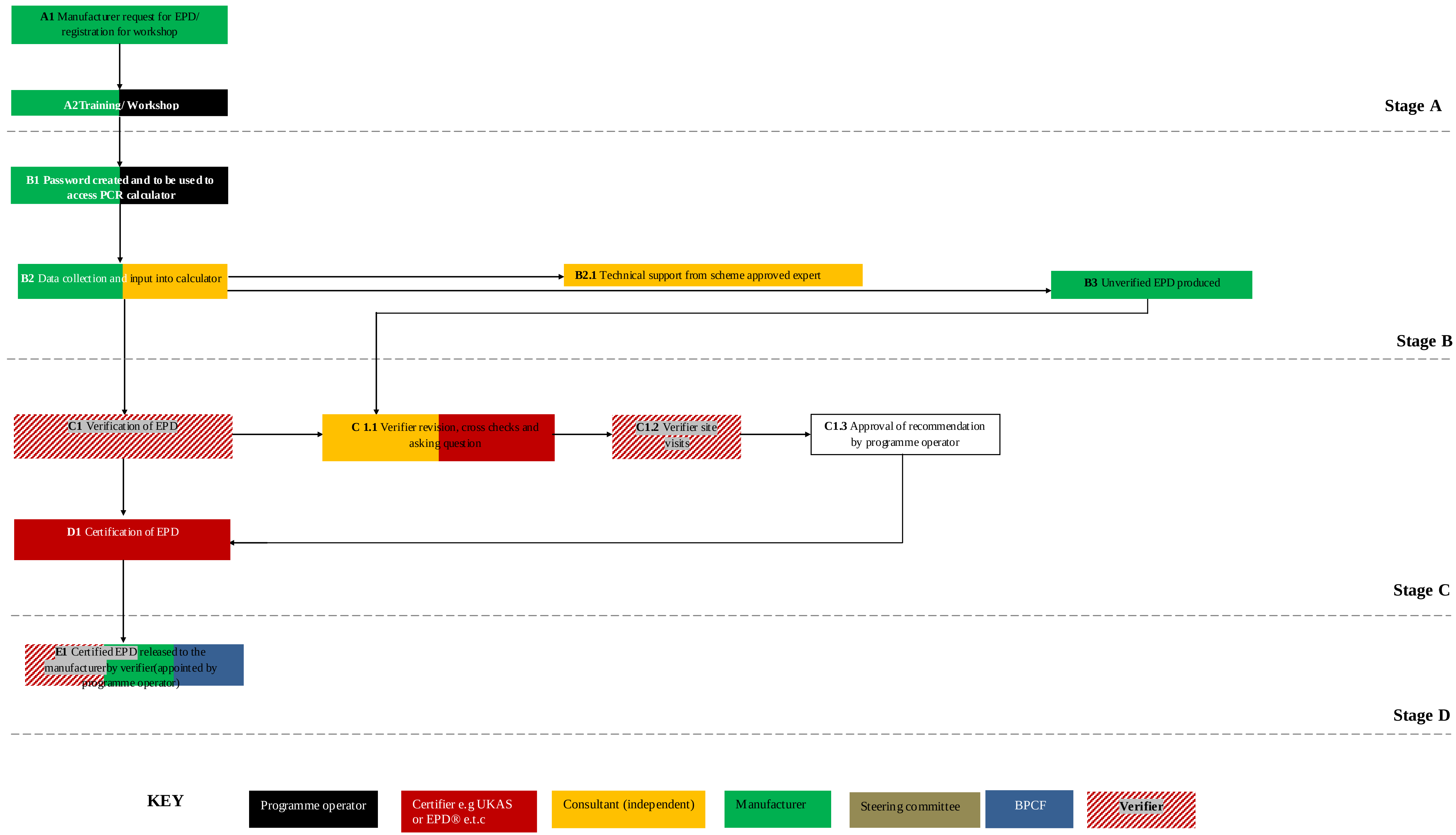


Figure 4.18: Functional process of the precast concrete industry EPD scheme

4.8 CHAPTER SUMMARY

This EngD research was aimed at embedding the principles of PS through the developing an EPD framework for the UK precast concrete industry. Five Work Packages were undertaken to help achieve the aim of the research. Each WP concludes with a summary and also reports the key findings of the WP. *WP1 focused on Sustainability and the precast concrete industry*. It sets out the general context of the research within the subject domain of sustainability and sustainable construction in relation to the UK construction, concrete and precast concrete industries. A state-of-the-art literature review was carried which included Government and industry reports and other academic sources. The RE was also actively involved in wide ranging activities (e.g. factory and site visits, attending seminars, meetings etc). *WP 2 focused on Conceptualising PS.* This was *a build-up review* carried out from conducting a state-of-art literature review from WP1. WP2 also reviewed the existing literature within the PS discourse and identified the key components of PS and an analysis of mandatory and voluntary PS schemes. Four interpretive and generic models of PS from the Automotive industry, Oil and Gas industry, Packaging industry and Electric and electronic industry were developed as part of WP2. *WP3* maps out the key industry environmental, social and economic impacts. An analysis and synthesis of KPI data from 2006 – 2011 was also conducted. In *WP4 the Key components of PS for the precast concrete industry* were defined, the specific industry interpretation of PS was established, drivers and barriers to implementing a PS scheme as well as the key conceptual and structural components and enabling mechanisms for doing so were identified. Lastly, *WP5* focused on developing a framework to embed the principles of PS into the UK precast industry, thereby creating a novel pathway towards more sustainable construction.

5. MANAGING THE DEVELOPMENT OF ENVIRONMENTAL PRODUCT DECLARATIONS: A FRAMEWORK FOR PRECAST CONCRETE MANUFACTURERS AND BRITISH PRECAST

5. 1 INTRODUCTION

This chapter presents a framework that has been developed to help precast concrete manufacturing companies and their trade body, British Precast, to understand the process through which EPD are developed, how EPD information is produced and shared at four different levels (0, 1, 2, 3 and 4). It serves as a continuation from Chapter Four Section 4.7. Importantly, it details the step-by-step process that a company would take to create its own EPD. The chapter also presents a spreadsheet tool that can be used to manage EPD data. The purpose of the framework is to ensure that the precast sector has a consistent approach to the development, management and contents of EPD and therefore the sector as a whole gains the most benefit from the EPD data that it publishes.

5.1.1 LIFE CYCLE MANAGEMENT FRAMEWORK TO ANALYSE EPD IN THE PRECAST CONCRETE INDUSTRY

The LCM framework provides a summary of how to analyse EPD in the precast concrete industry. This starts from the commissioning of LCA consultants by the relevant stakeholders (i.e British Precast member companies through their representatives' e.g Sustainability managers). When the EPD is carried out, an analysis is run through the 2EI developed. Improvements are then made through stakeholder engagement process through focus groups for example; green product recyclers, carbon experts, researchers, consultants etc. Approval is then given by individual company board or the relevant decision making group etc. Options are then provided to choose new product suppliers, make changes to product/ process and investments in new green technologies are explored. The final stage is to make the EPD.

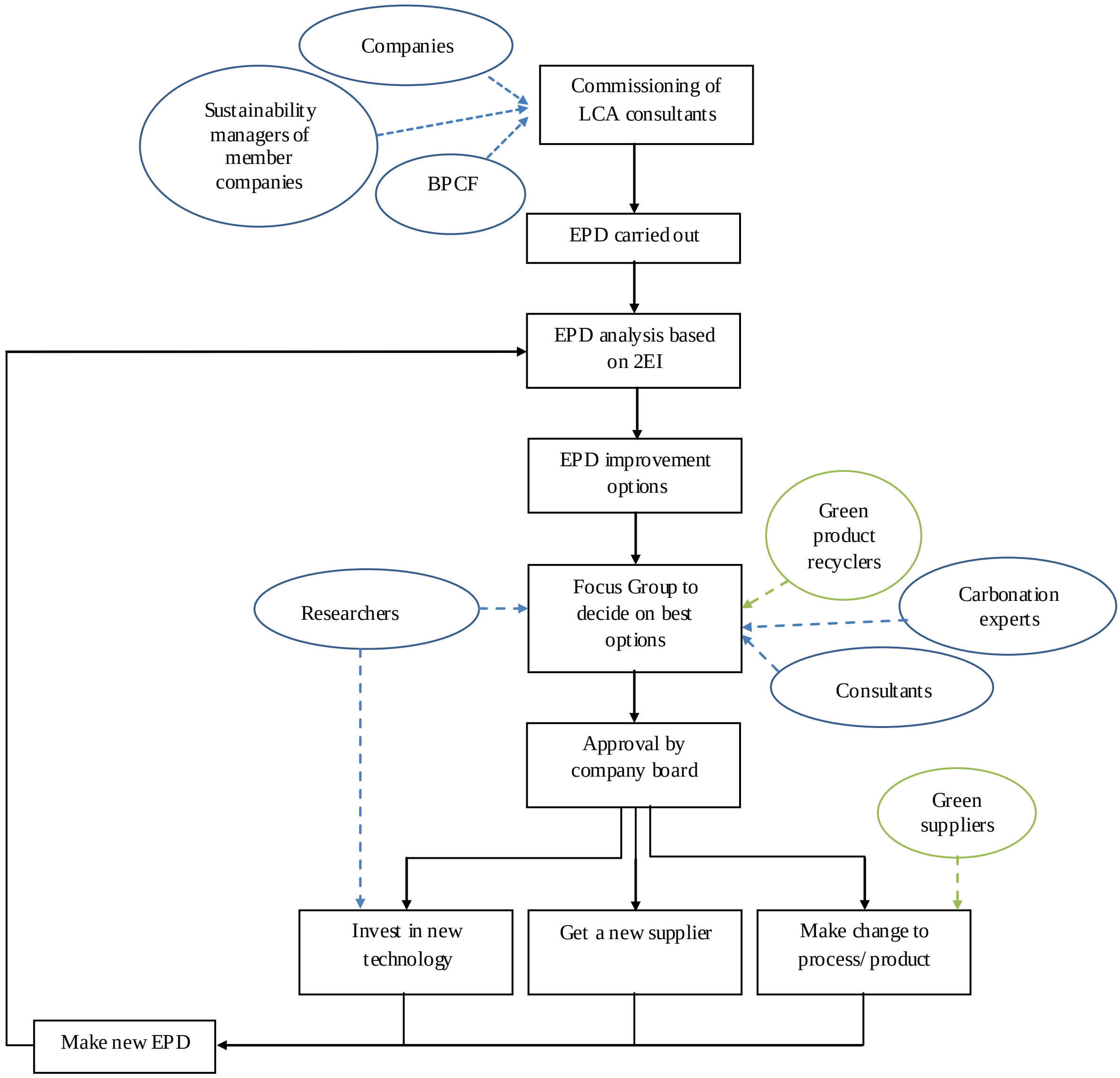


Figure 5.1: Life Cycle Management Framework to Analyse EPD in the Precast Concrete Industry.

5.2 FRAMEWORK STRUCTURE AND DEVELOPMENT PROCESS

There are two key components to the structure of the framework.

First, it is important to show the relevance of EPD in the sector. Secondly, it is important to show exactly how an EPD should be developed within a company. The following sections present these two aspects in detail.

5.2.1 INFORMATION STRUCTURE

Figure 5.2 presents a three level arrangement, which shows how EPD information is relevant at a number of different levels in the precast concrete sector. Table 5.2 shows all the levels, elements and their respective description.

5.2.2 JUSTIFICATION FOR THE USE OF ECO-POINTS IN EPD

Caveat *

BS 15804 does not allow for Eco points to be used in the EPD process, so it could be said that this research would not result in EPD that are compliant with the standard. However, the purpose of this research was to test a new procedure at sector-level and to gauge its effectivesness through a benchmarking exercise. Hence, relevant Eco points were applied in the LCMod calculator, to compute the total environmental impacts Eco points index (2EI) for a precast concrete element/product. This enabled the research to test the outputs as a proof of concept exercise.

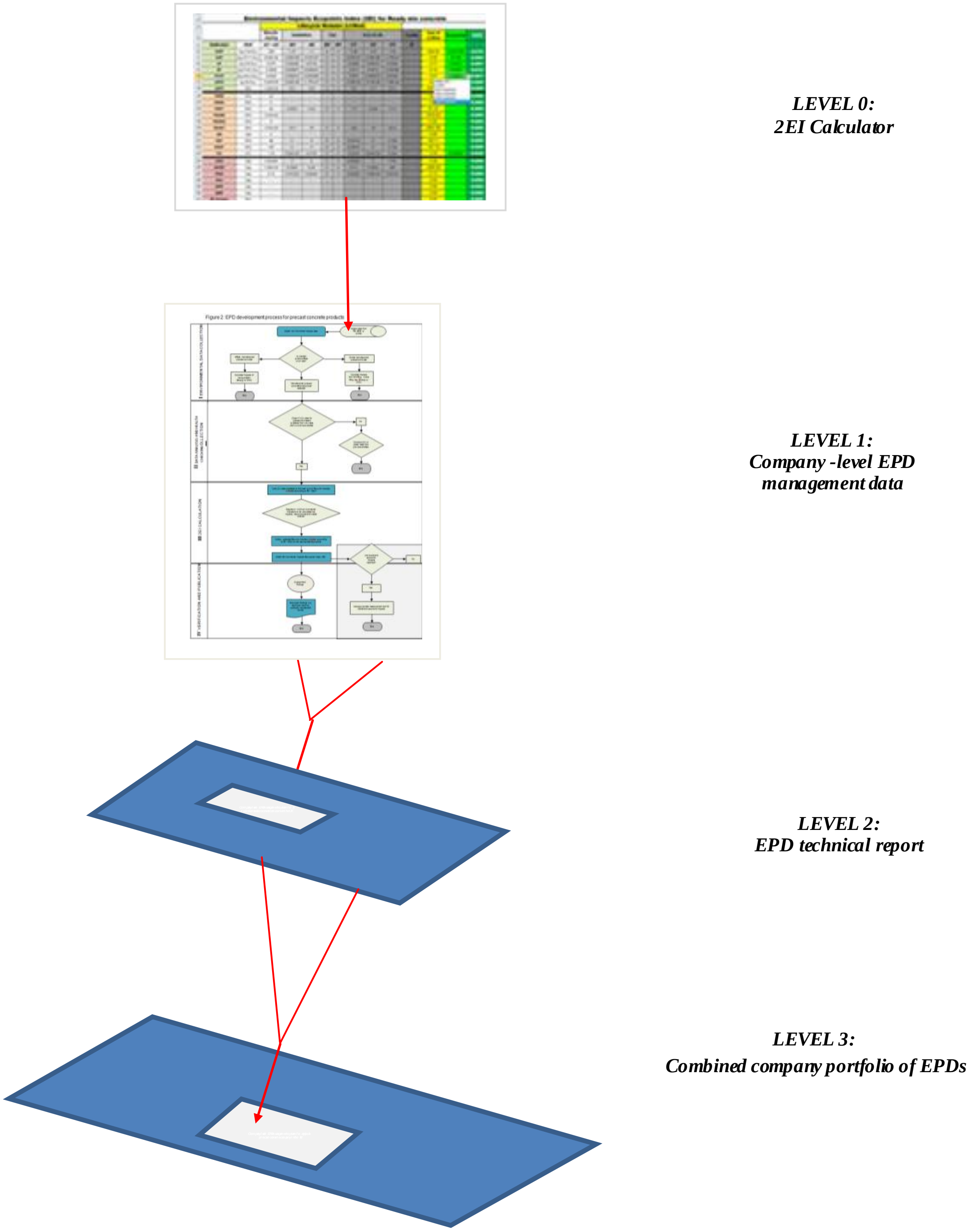


Figure 5.2: The four levels within the EPD development process for precast manufactured products.

Table 5. 1: Gives explanation of four levels within the EPD development process for precast products

Level	Element	Description
0	Eco-point Index Environmental Impacts (2EI) Calculator	The 2EI calculator was developed in Microsoft (MS) Excel spreadsheet software 2013 version 15, to help in processing and presenting environmental impacts data in a simple, tabular format.
1	Company - level EPD management data	This level maps out the entire process for the EPD development for precast concrete products. It consist of four key stages which includes; environmental data collection; data analysis and health checking; 2EI calculation and, verification and publication.
2	EPD technical report	In this level, a technical report that contains vital information regarding the procedure of EPD production based on BS EN 15804, ISO 21930, ISO 14025 and all other relevant standards to EPD development are used. The results from the EPD conducted are then produced and include in the technical report. The report will be available electronically and on the web.
3	Combined company portfolio of EPDs	This level consists of series of EPDs conducted within individual member companies. A portfolio of EPDs is created and stored in a bank for industry and stakeholder use. The EPD portfolios will be available electronically and on the web.

5.3 AIM AND BENEFITS OF THE FRAMEWORK TO THE INDUSTRY

The main aim of this framework is to provide a simplified and robust outline of the major steps and process involved for the development of EPD and how EPD information can be used and shared across the industry in an efficient and effective manner. A summary of the framework is provided in Appendix C.

5.3.1. BENEFITS OF THE FRAMEWORK

a. It will help in the provision of Environmental data and LCA data.
b. It will facilitate easy access to environmental data as well as help in analysing data.
c. The framework will link to the whole manufacturing process and the management process through the use of software.

5.3.1.1. EPD DEVELOPMENT PROCESS

Figure 5.2 shows the process flow for the development of an EPD for precast concrete element (s) or product (s), within a particular company. It has been designed in the form of a simplified flow chart for use by a typical precast concrete company in the UK.

The precast concrete elements or products are selected based on their specifications. All impacts at these stages should be included for example energy and transport impacts.

At company level, decision will be taken to establish the product life cycle information to be included according to EN BS 15804 (2012).

Data from manufacturers will serve as a primary data sources for admixtures, waste, energy, waste water e.t.c. While, Environmental data can be obtained from a data bank which are obtained from Eco invent, GaBi or a similar body, or through conducting an Life Cycle Analysis (LCA) - as explained later in Section 3, where an explanation is provided for life cycle stages A1 – A3 which includes; raw materials supply (A1), Transport (A2), and Manufacturing (A3). In accordance with BS EN 15804, this example would be classed as "Cradle- to- gate with options".

Table 5.2: Gives a detailed explanation on how the EPD development process for precast concrete products could be:

Code	Key process	Description
I	Environmental Data Collection	This is the first key step in the EPD development process. Primary data (for example; energy use, water use, waste e.t.c) are all obtained from the primary manufacturers. Environmental impacts data can be obtained from British Research Establishment (BRE), or databases such as Eco invent, GaBi or a similar body. Data is then used for the selected precast concrete product either on-site or off-site precast concrete product or element. Here considerations should be made for all other impacts e.g energy from forklifting, cranes e.t.c.
II	Data Analysis and Health Checking	This stage consists of Life Cycle Analysis (LCA) data checks. It establishes whether LCA data is available from previous studies that can be used if available from a data bank. If the required data for use is not available, then an LCA is required to obtain the right data.
III	2EI Calculation	This stage involves calculating the Environmental Impacts Eco-point score (2EI). This is carried out by using the available LCA data obtained from Code II. The LCA data is used to calculate the total sum of lifecycle modules (LCMods) according to BS EN 15804: 2012. Out of the available 17 modules, 16 will be considered (Module D which is Reuse/ Recovery and Recycling is out of the scope of this work). Environmental indicators to be calculated are selected from impacts, resource use and waste/ outputs. The selected LCMod are then multiplied by the appropriate Eco-points score. The Eco-points score used where developed in 2007. Green Guide to Specification BRE Materials Industry Briefing Note 3b: Normalisation (BRE, 2005) was also used. See Table 5.6 for the normalisation factors used. At the end of these stages, if social and economic impacts calculations are need; then the appropriate tool or calculator should be used or developed.
IV	Verification and Publication	This stage is the final stage that involves two main processes; Verification and Publication. The 2EI calculation conducted in Code III will be reviewed by an independent in house consultant or appointed third party. The verified results will then be published in the form of a technical report or publically accessible format.

The flow chart is shown in Figure 5.3 and the keys to the symbols are shown below:

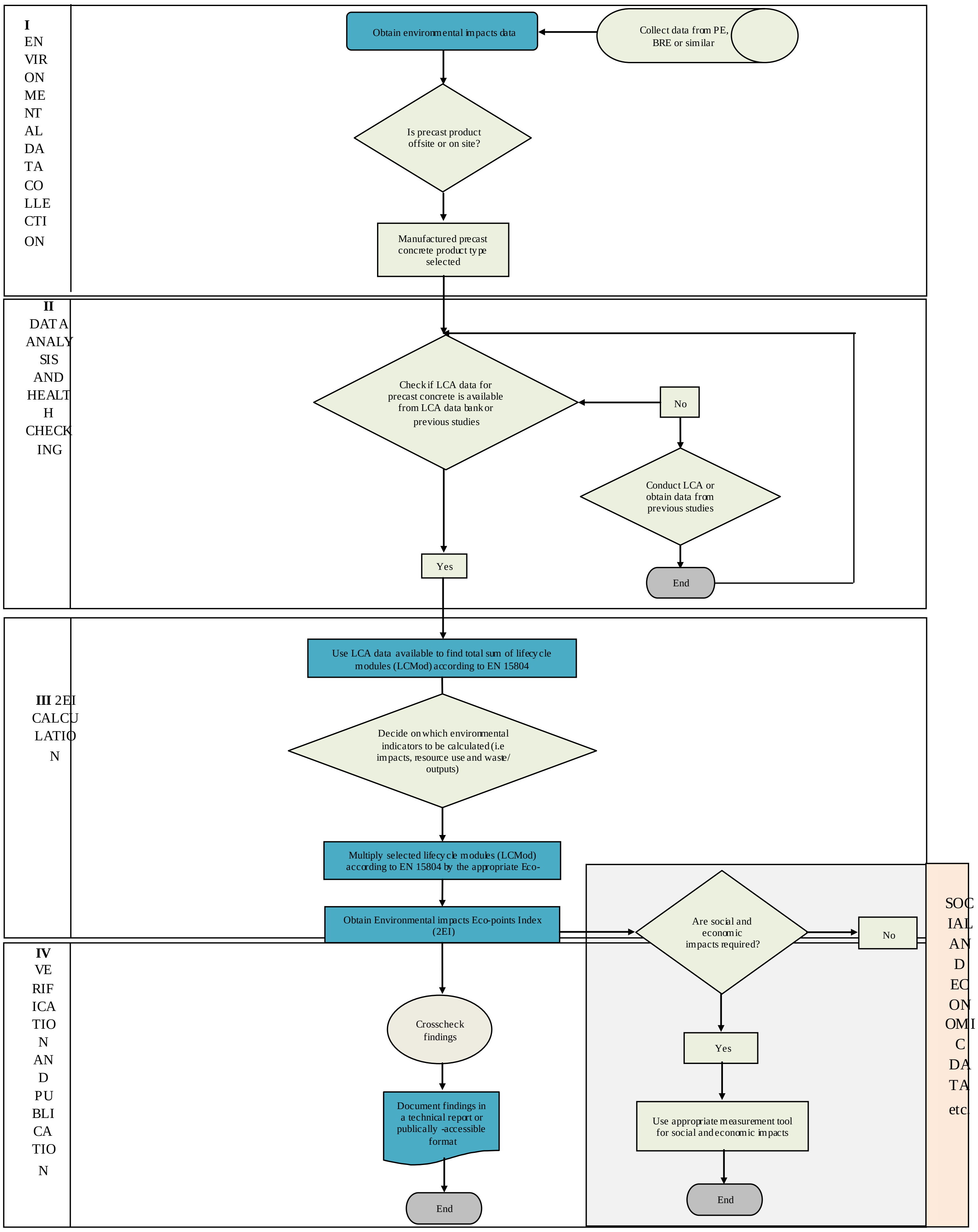
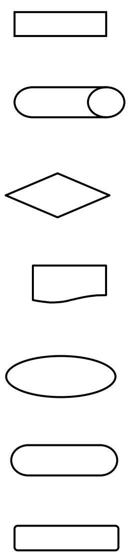


Figure 5.3 EPD development process for precast products

KEY:



A rectangle represents a process, task, action, or operation.

A direct access storage represents a bank or storage.

A diamond represents a

A rectangle with a curved bottom represents a document or report.

A circle represents a verification exercise and

A Terminal or Terminator Shape represents the end of a process.

A rounded rectangle represents an alternate process.

5.4 DATA FOR THE EPD

Having explained the overall structure and process, this section focuses on the data that is used to populate an EPD. Specifically, it presents the Environmental Impacts Eco-Points Index (2EI) calculator, which has been developed specifically for the sector.

Figure 5.4 shows a Microsoft Excel spreadsheet for 2EI for precast concrete and Figure 5.5 shows a worked example for concrete.

5.5 THE ENVIRONMENTAL IMPACTS ECO-POINTS INDEX (2EI) CALCULATOR FOR PRECAST CONCRETE PRODUCTS

While it is possible to commission a specialist consultant to product an EPD, the development of a stand-alone tool that can help precast manufacturers to process and interpret their own environmental data could have cost, time and learning advantages. For these reasons, a simple calculator has been developed for their use. It has been informed by the life-cycle assessment report published by Aggregate Industries (Aggregate Industries, 2013), which was developed with help from BASF Chemicals (BASF, 2013) and using primary data from Aggregate Industries and PE International.

The 2EI calculator was developed in Microsoft (MS) Excel spreadsheet software (2013) version 15, to help in processing and presenting environmental impacts data in a simple, tabular format. As spreadsheet software, it has the advantages of ease of use, functionality, flexibility and a simple user-friendly interface.

The 2EI spreadsheet has columns and rows based on a grid of cells, as shown in Figure 5.3. It includes a new function: Life cycle modules (LCMods) from Product stage (A1 – A3), Construction process stage (A4-A5), Use stage (B2 –B7), and End of life (C1 –C4). The LCMods term was coined specifically for this particular research to describe the all the Life Cycle modules stated in BS EN 15804.

A cell was also developed for a ‘credits’ score – which are obtained from BREEAM environmental weightings.

Figure 5.5 shows the different types of EPD with respect to life cycle stages covered and life cycle stages and modules for the building assessment from BS EN 15804 p.14 and Table 5.3 explains the 2EI columns and rows.

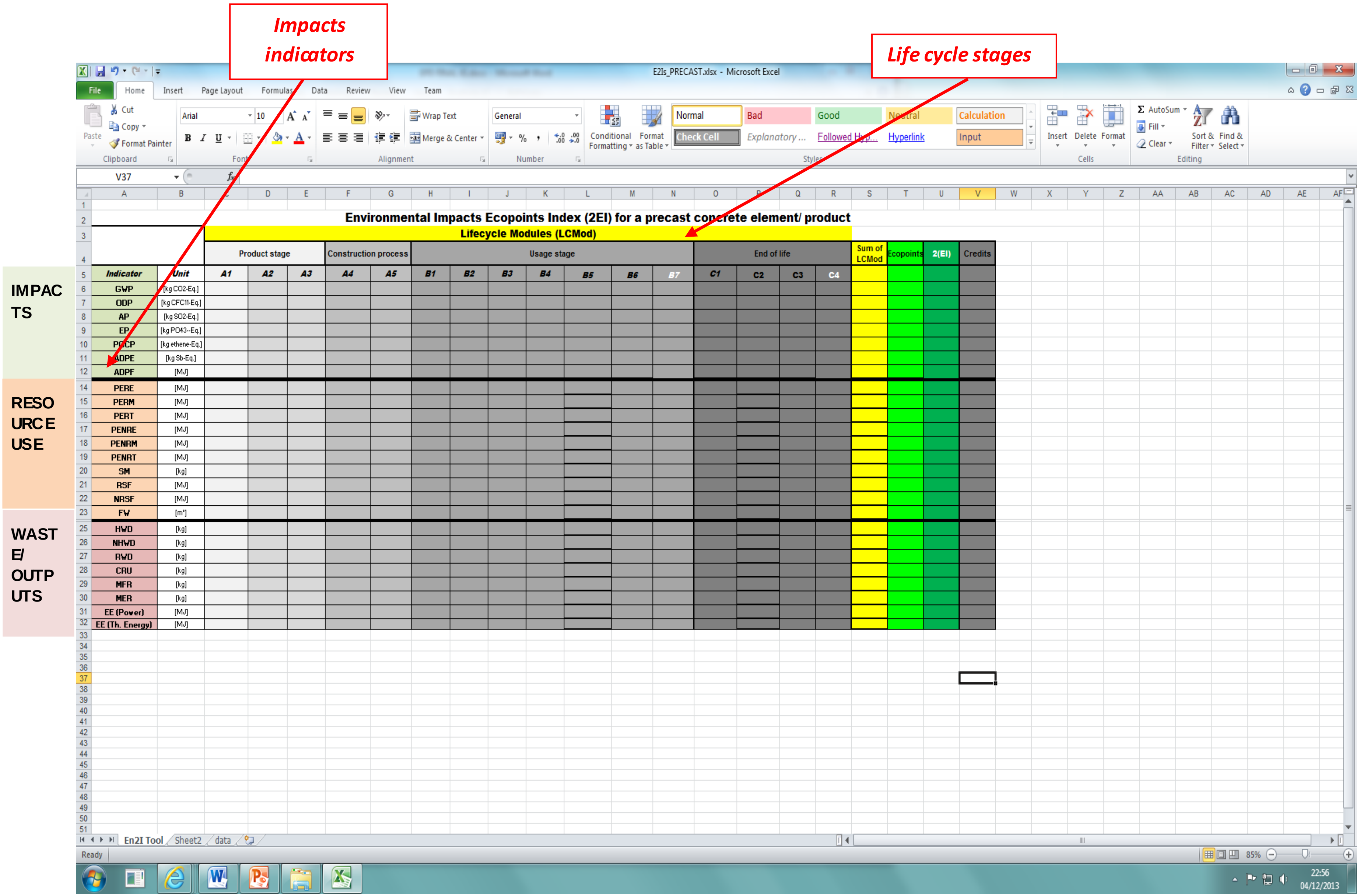


Figure 5.4: Screen shot from MS Excel spreadsheet for Environmental Impacts Eco points Index (2EI) for precast concrete.

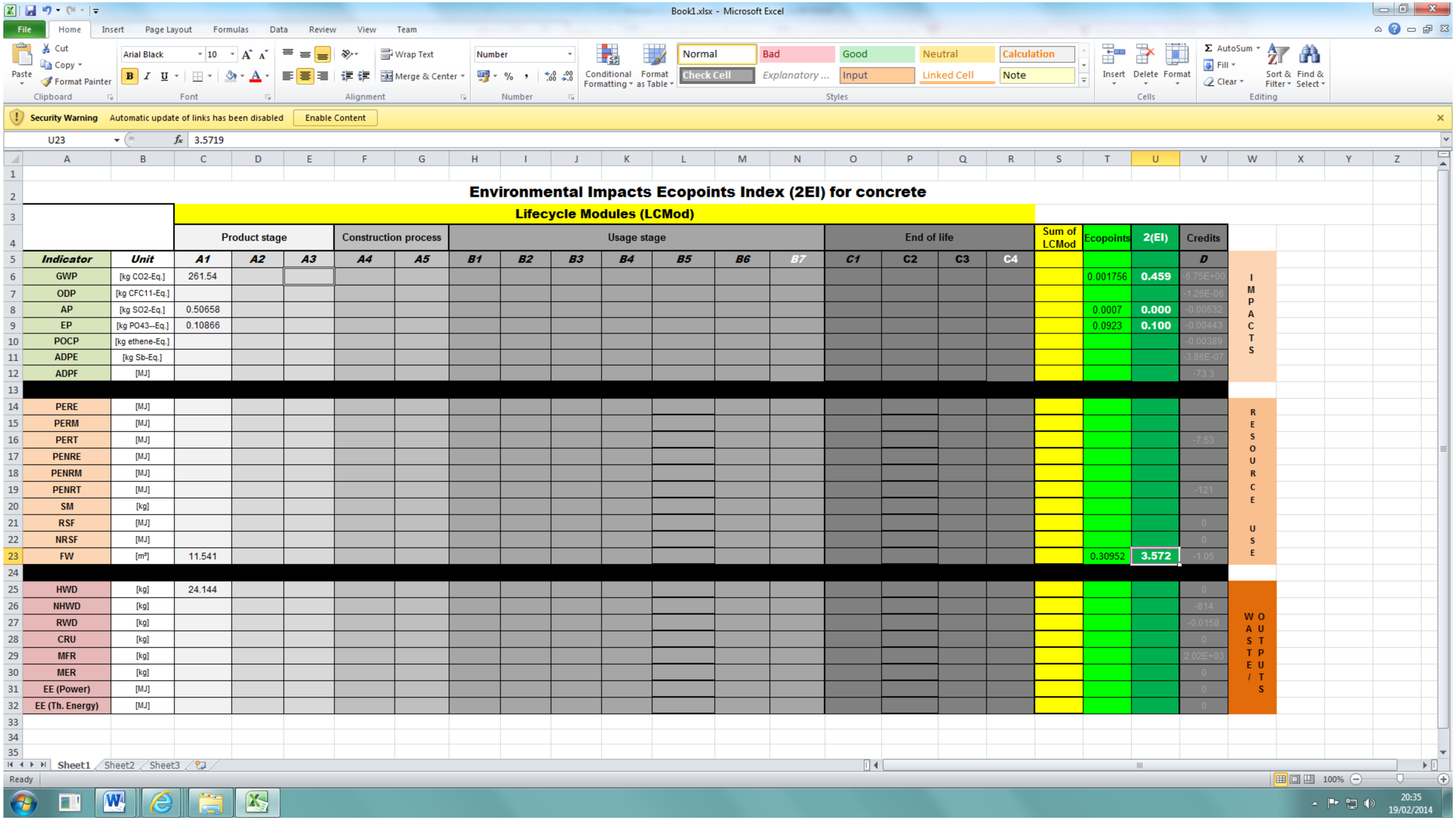


Figure 5.5: Screen shot from MS Excel spreadsheet for Environmental Impacts Eco points Index (2EI) for concrete.

Table 5.3: 2EI cells and rows with description

Column letter	Description	Row number	Description
A	Shows environmental indicators	2	Describes the title of the spreadsheet
B	Shows the units of environmental indicators	3	Shows the Lifecycle Modules (LCMods) title
C	A1 is a Product stage that represents Raw material supply (extraction, processing, recycled materials)	4	Shows each of the Lifecycle stages
D	A2 is a Product stage that represents transport to the manufacturer	5	Shows indicators, units as well as LCMods categorised from A1-A3, A4-A5, B1-B7, C1-C4, Sum of LCMods, Ecopoints, 2(EI) and Credits
E	A3 is a product stage that represent manufacturing	6	Shows Global warming potential
F	A4 stands for construction process stage transportation to the building site	7	Depletion potential of the stratospheric ozone layer
G	A5 represents a construction process stage for installations into the building	8	Acidification potential of land and water
H	B1 represents the use phase and denotes use/ application	9	Eutrophication potential
I	B2 represents the use phase and represents maintenance	10	Formation potential of tropospheric ozone photochemical oxidants
J	B3 represents the repairs stage	11	Abiotic depletion potential for non-fossil resources
K	B4 represents replacement	12	Abiotic depletion potential for fossil resources
L	B5 denotes refurbishment	13	Use of renewable primary energy excluding renewable primary energy resources used as raw materials
M	B6 denotes operational energy use	14	Use of renewable primary energy resources used as raw materials
N	B7 represents operational water use	15	Total use of renewable primary energy resources
O	C1 denotes deconstruction demolition	16	Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials
P	C2 denotes transport	17	Use of non-renewable primary energy resources used as raw materials
Q	C3 represents End of life waste processing	18	Total use of non-renewable primary energy resources
R	C4 denotes End of life disposal	19	Use of secondary material
S	Sum of Lifecycle modules	20	Use of renewable secondary fuels
T	Ecopoints	21	Use of non-renewable secondary fuels
U	2(EI)	22	Use of net fresh water
V	Credits	23	Hazardous waste disposed
		24	Non-hazardous waste disposed
		25	Radioactive waste disposed
		26	Components for re-use
		27	Materials for recycling
		28	Materials for energy recovery
		29	Exported energy per energy carrier

EN 15804:2012 (E)

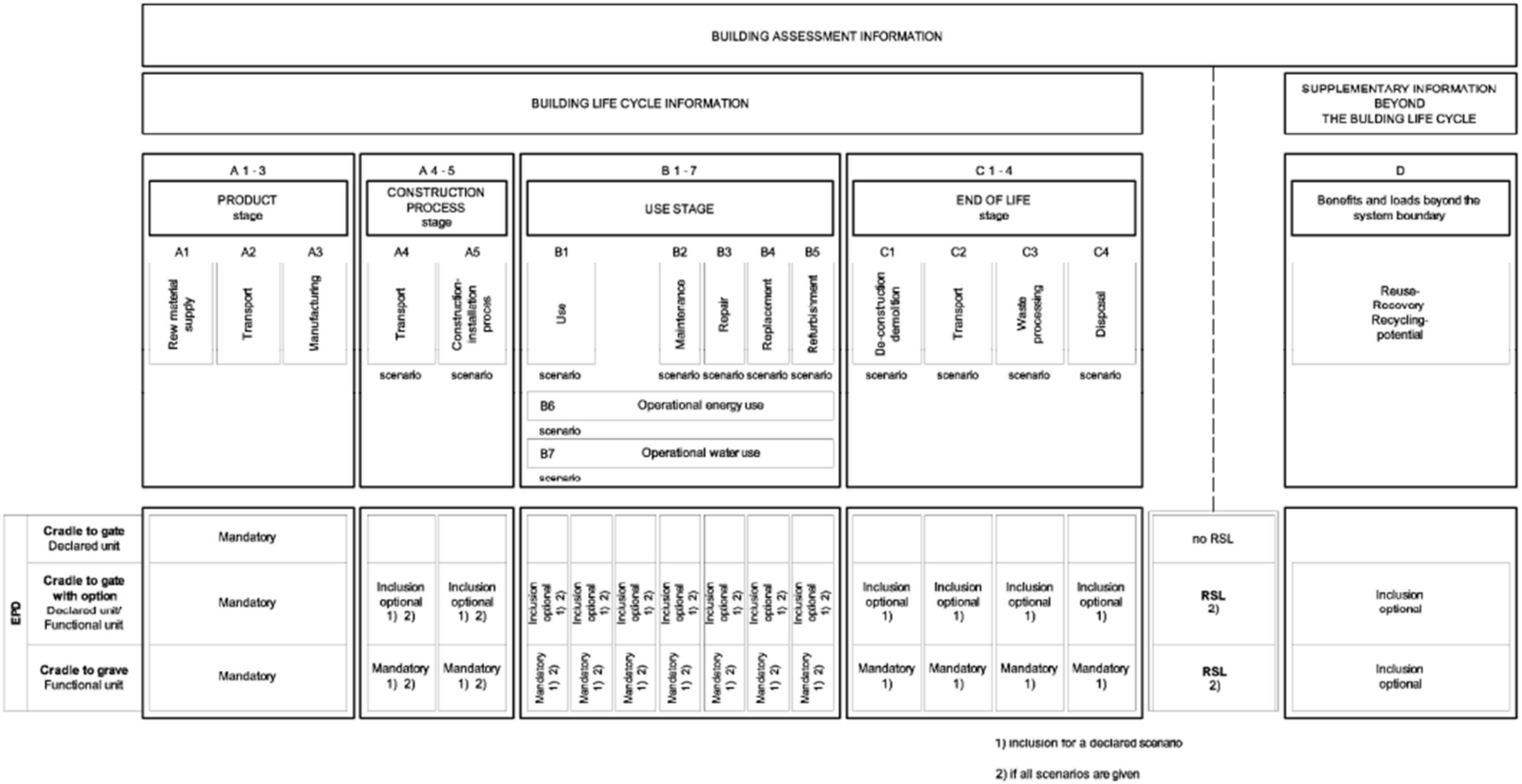


Figure 5.6: Types of EPD with respect to life cycle stages covered and life cycle stages and modules for the building assessment. Source: BS EN 15804 (2012, p.14).

Table 5.4: Environmental indicators used for 2EI calculator

Environmental indicator abbreviation	Environmental Indicator	Unit
GWP	Global warming potential	[kg CO_2-Eq.]
ODP	Depletion potential of the stratospheric ozone layer	[kg CFC11-Eq.]
AP	Acidification potential of land and water	[kg SO_2-Eq.]
EP	Eutrophication potential	[kg PO_4^{3-}-Eq.]
POCP	Formation potential of tropospheric ozone photochemical oxidants	[kg ethene-Eq.]
ADPE	Abiotic depletion potential for non-fossil resources	[kg Sb-Eq.]
ADPF	Abiotic depletion potential for fossil resources	[MJ]
PERE	Use of renewable primary energy excluding renewable primary energy resources used as raw materials	[MJ]
PERM	Use of renewable primary energy resources used as raw materials	[MJ]
PERT	Total use of renewable primary energy resources	[MJ]
PENRE	Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials	[MJ]
PENRM	Use of non-renewable primary energy resources used as raw materials	[MJ]
PENRT	Total use of non-renewable primary energy resources	[MJ]
SM	Use of secondary material	[MJ]
RSF	Use of renewable secondary fuels	[MJ]
NRSF	Use of non-renewable secondary fuels	[MJ]
FW	Use of net fresh water	[m^3]
HWD	Hazardous waste disposed	[kg]
NHWD	Non-hazardous waste disposed	[kg]
RWD	Radioactive waste disposed	[kg]
CRU	Components for re-use	[kg]
MFR	Materials for recycling	[kg]
MER	Materials for energy recovery	[kg]
EE(Power)	Exported energy [power]	E
EE (Th.Energy)	Exported energy [thermal]	[MJ]

Source: EN 15804 (2012, p.30)

5.6 HOW THE SPECIFIC FUNCTION LCMOD IS CALCULATED

To calculate the sum total of life cycle modules, the following formula was used:

Sum of LCMod = A1+A2+A3+B1+B2+B3+B4+B5+B6+B7+C1+C2+C3 +C4

To calculate the Eco points score, Green Guide to Specification BRE Materials Industry Briefing Note 3b: Normalisation (BRE, 2005) was used. The normalisation factors used are given in Table 5.7, which are based on those for ready-mix concrete.

Table 5.5: Normalisation factors - impact per citizen of Western Europe (BRE, 2005).

Category	**Per Citizen**	**Unit**
Abiotic depletion	39.1	kg Sb eq.
Global warming (GWP100)	12.3	tonne CO2 eq. (100 yr)
Ozone layer depletion (ODP)	0.217	kg CFC-11 eq.
Human toxicity	19.7	tonne 1,4-DB eq.
Fresh water aquatic ecotoxicity.	13.2 tonne	1,4-DB eq.
Terrestrial ecotoxicity	123	kg 1,4-DB eq.
Photochemical oxidation	21.5	kg C2H4eq.
Acidification	71.2	kg SO2 eq.
Eutrophication	32.5	kg PO4 eq.
Solid waste	*	tonne solid waste
Radioactivity	0.000241	mm3 high level waste
Minerals Extraction	*	tonne minerals extracted
Water Extraction	*	m3water extracted

* Normalised impact to be calculated.

The environmental impact data obtained from the 2EI spreadsheet can be used to calculate the total environmental impacts, by multiplying the environmental impacts category by the eco-points. The result is the Environmental impacts Eco point index (2EI) for the selected precast concrete element/ product.

5.7 CHAPTER SUMMARY

As part of an overarching PS initiative for the precast concrete industry, EPD development can offer a realistic and achievable starting point for the mitigation of key environmental impacts. The central contention of this chapter is that EPD can provide reliable, verifiable and accurate information concerning the environmental performance and credentials of precast concrete products. Various examples of wide usage of EPD in different countries and industries point to the fact that their developments help manufacturers, users and other stakeholder towards more transparent disclosure of environmental information of products and services. The UK precast concrete industry has an opportunity to develop an industry-wide EPD that is centralised and managed by the trade federation with third-party independent verifiers as PCR management consultants. This will go a long way in positioning the industry to voluntarily market its green credentials in a more efficient and effective manner while also reducing its environmental footprints/impacts without the enforcement of impending European Union legislation. Nonetheless, as mentioned previously in respect to implementation of any PS initiative, an EPD needs to be delivered at company level, So while the sector-level bodies within the precast industry can be instrumental, it will be a matter for the individual member companies to invest in their own product EPDs. In this case, the barriers identified within Section 4.5 will be material and so the sector-level bodies may need to investigate further how such barriers might best be overcome to convince their members to act.

A LCM framework development has been identified and suggested pre and post-EPD stages. The precast concrete industry needs to develop a Life Cycle Management (LCM) strategy that includes and encompass all relevant stakeholders and main actors upstream and downstream the supply chain/ value chain and life cycle of precast concrete products as recommended in page 139. These stakeholders should be selected or chosen from the major constituent concrete ingredient manufactures (Cement, steel, quarry owners, PFA, GGBS), designers, manufacturers, users, clients and government. This will help the industry map out all the positive and adverse effects on the use of concrete and contentious issues such as; embodied impacts from cement, green guide ratings, degree of apportioning responsibility, transfer of responsibility of environmental, social and economic impacts through (i.e. shared responsibility, stakeholder responsibility, extended producer responsibility, producer responsibility, user responsibility and client responsibility or government responsibility), end of life for example; time frame of precast concrete product use, inheritance of impacts, take-back, reuse, recycling, refurbishing, waste e.t.c

6. RESEARCH FINDINGS, IMPLICATIONS, RECOMMENDATION AND CONCLUSION

6.1 INTRODUCTION

This chapter reports the key findings of the EngD research programme. It also includes sections on overall implication of these findings to the UK precast concrete industry with particular emphasis on British Precast member companies. The chapter has six sections which includes; the introduction, key findings, research outcomes, industrial impact, critical evaluation and recommendations for the industry and potential areas for further research. The research assesses the potential of PS in the UK precast concrete industry and the attendant objectives reflect the recent developments around EPD, since these had potential to become a significant means through which PS could be implemented in the precast concrete sector. This aim was achieved through a number of research tasks shown in Figure 1.1. Each of the five work packages were delivered via various research tasks in line with the aim of embedding the principles of product stewardship (PS) through developing an environmental products declaration (EPD) framework for the UK precast concrete industry, thereby creating a novel pathway towards sustainable construction. The objectives of the research were to:

1. define the UK precast concrete industry's key sustainability issues and identify its most significant impacts;
2. explore the possible characteristics and implications of implementing product stewardship within the precast concrete industry;
3. analyse the sustainability performance of the precast concrete industry through its reported key performance indicators;
4. investigate the use of environmental products declaration (EPD) within the precast industry as a means of implementing PS; and
5. develop and validate a framework for introducing EPDs in the UK precast concrete industry.

The key outputs were in the form of academic papers in conferences and journals. A summary of the key phases within the research is given in the following four sections.

6.2 UNDERSTANDING SUSTAINABILITY IN THE PRECAST INDUSTRY

The start-up stage of the EngD research (WP1) comprised: precast concrete site visits; attending seminars; industry focused meetings; a thorough state-of-the-art literature review; review of government and industry reports; and desktop studies to understand the key issues that are topical within the subject domain with particular emphasis on the concept of sustainable development, sustainable construction and its application to the precast sector. These identified areas formed an integral part of the research aim and addressed Objective One of the EngD research (To define the UK precast concrete industry's key sustainability issues and identify its most significant impacts). Over the last two decades, the concept of sustainable development has become an organisational imperative within the construction industry. Government and various stakeholders within the construction industry are demanding more sustainable construction leading to the publication of various policies, reports and legislation. These reports were reviewed as part of the research (see result in Paper1 Appendix A). Construction product manufacturers and suppliers were identified as crucial components of the supply chain towards the delivery of a more sustainable future (CPA, 2007) and corporate sustainability can be achieved through addressing key sustainability issues throughout an organisation's supply chain (Adetunji *et al.*, 2008: 161). Within the UK concrete industry, an industry-wide strategy for sustainable construction was launched in 2008 with strategic objectives and commitments in the form of targets. The UK precast concrete industry thereby developed a sustainability strategy aimed at measuring, improving and promoting its environmental, social and economic credentials. To achieve Objective One through WP1, the key sustainability issues within the precast industry were therefore identified through a comprehensive literature review, study of industry reports, and participation in events with the industry sponsor and visits to production facilities (this also forms part of Paper 2 Appendix B).

6.3 PS AND THE PRECAST INDUSTRY

WP2 (Objective Two: To explore the possible characteristics and implications of implementing product stewardship within the precast concrete industry) investigated the relationship between PS and the precast concrete industry as a means of improving sustainability performance. A state-of-the-art literature review was carried out to understand the concept of PS and review its various definitions. The literature review also included a desktop comparative analysis and synthesis of different PS schemes from four selected industries with dedicated PS schemes, which included; the electric and electronics industry, chemical and petro-chemical industry, automotive industry and the packing and packaging industry. The review provided an understanding of the concept of PS, its definition, key principles, components, its key stakeholders, tools used and varying level of PS implementation from micro (company) level to macro (continental) levels. Through this review, models were developed to show overlapping relationship of strategic PS implementation in the schemes studied. The models were used in subsequent data collection with industry interviewees and the key findings are presented in Paper 2 (see Appendix B). Interviews were used to provide robust insights into the perception of what PS is and what it will likely mean for the industry and to identify similarities and peculiarities of individual member companies of BPCF in regards to the sustainability management of the industry. The RE also participated in webinars, internet-based discussions with PS experts and companies with PS schemes.

The drivers for PS implementation range from revenue growth through product differentiation (Hart, 1997); to avoid being vulnerable in future, (Armstrong and Kotler, 2006); to reduce cost and liabilities and, to be become more responsible through proper ethical management (Johnen *et al.*, 2000). As highlighted earlier, the UK precast concrete industry has been under pressure from various stakeholders to reduce its sustainability impacts. The industry could therefore benefit from PS as it can offer a long-term framework for managing life-cycle impacts.

The interviews found a good understanding of the concept of PS in the precast industry, but no existing robust and coherent framework for LCM. All the research findings are documented in Paper 2 (Appendix B) and Paper 3 (Appendix C).

6.4 MAPPING KEY PRECAST CONCRETE INDUSTRY IMPACTS

Objective Three (WP3) – analysis of the sustainability performance of the precast concrete industry through its reported key performance indicators was based on an identification of the key environmental, social and economic impacts of the precast concrete industry through a literature review, followed by data analysis of industry statistics (2006-2011) and information provided by precast manufacturer members of BPCF. Previous EngD Research conducted for the UK precast concrete industry by Holton *et al.*, (2010) suggested that the key impacts of the industry are divided into three categories namely; environmental, social and economic impacts (after Elkington, 1997). Concrete's key environmental and social impacts occur in six main stages of its life-cycle which include; raw material extraction, cement and addition manufacture; production of ready mixed concrete and precast concrete product; construction of buildings and infrastructure using concrete; operational use in the built environment and end-of-life disposal and recovery. The cement industry has been identified as being responsible for the majority of emissions associated with concrete (Sakai, 2008; Bijen, 2002; CSI, 2012), but There are variations depending on cement content and curing times (Elhag *et al.*, 2008). This is pertinent to the various regimes and standards of manufacture within UK precast production, but the main outcome from this task was to identify that; materials, energy and climate change mitigation and adaption, water management and waste management are the principal impact categories for the precast sector. The outcome of this task was presented to the Sustainability and Environment Committee of BPCF and is documented in Paper 3 (Appendix C).

6.5 DEVELOPING AND VALIDATING A PRECAST EPD FRAMEWORK

Objective 4 – To investigate the use of environmental product declarations (EPD) within the precast industry as a means of implementing PS (WP 4) and Objective 5 -Develop and validate a framework for introducing EPD in the UK precast concrete industry (WP4), deliberate what is EPD, the potential of EPD as a communication and reporting tool for PS and life cycle management information within the precast concrete industry. The focus on EPD was born out of the need for the precast concrete industry to improve on its current sustainability performance and stewardship of its products and service. It will also provide its key stakeholders both within and outside the construction industry with accurate, third party verified environmental information about it products and help clients and designers with product comparison e.g the choice of a precast concrete product over a steel, wood or glass product as the case may be. Another reason was the necessity by the industry's focus on LCA in preparation of Type III EPD. The review focused on the existing literature on EPD and considered how the precast concrete industry could develop an industry scheme. Interviews with three selected industry experts on sustainability and EPD were also carried out, the results from which all supported the development of an EPD framework for the precast concrete industry which consists of five stages (A to E) with each stage identifying specific preparation requirements, work stages, stakeholder responsible to carry out each associated task and the exact stakeholder responsibility at each stage, where applicable.

To assess and validate the EPD framework, an industry focus group and short questionnaire survey were carried out with ten member companies of BPCF. All the ten companies that took part in the focus group and survey are members of the BPCF Sustainability and Environment Committee. At this early stage of the subject's development, it was not surprising that responses varied, but there did seem to be consensus on several aspects; the respondents agreed that the EPD framework:

- is potentially useful because it is sector based, complies with all relevant standards e.g. BS 15804, ISO 14025 and could offer an effective certification route with a standard methodology;
- has a governance structure that appears to be credible, transparent and effective; and,
- will provide reassurance to clients/customers.

However, there were mixed feelings with regards to the full implementation of the EPD framework by member companies owing to concerns about cost and levels of experience and knowledge on EPD. The companies felt that the need for industry-specific Training, the role of legislation, recognition by clients and in BREEAM were all pertinent factors in determining the future development path for any such programme. The questions, coding and patterns of the survey can be found in Appendix F.

6.6 INDUSTRIAL IMPACT

This section provides a snapshot of the industrial impact of the research to BPCF which is the industrial sponsor and its members (i.e. precast concrete manufacturers). In response to the demand made by various precast concrete industry stakeholders and the industry commitment to sustainability, British Precast developed a sector sustainability strategy in 2008. The strategy provided the industry with a sustainability model that helped the industry to better understand sustainability, implement and measure its performance. In line with BPCF's responsibilities as an effective trade federation that serves the interest of its members, this research focused on identifying the key components of PS for the precast industry and how the principles of PS could be applied (e.g. through EPD) to mitigate the environmental impacts of precast concrete products. The research identified that elements of PS are already evident within the industry through EMS, responsible sourcing and strategies to mitigate various impacts (water, waste, energy, impacts associated with Portland cement content and need for replacement etc.), but, results from this research have shown that PS is rather disjointed and the communication of initiatives associated with PS requires a robust and coherent approach. New EPD studies provide an opportunity for the industry to develop, capture and promote its PS credentials, which will help BPCF better align its sustainability initiatives from a life cycle approach. The EPD framework developed will help BPCF encourage its membership to get involved in an industry-wide EPD scheme. Indeed, for its manufacturing member companies, the research has produced a clear framework through which they can each continue their sustainability journey using PS as a model, in this case demonstrated via the development of an EPD scheme. The research has shown that already some precast concrete companies have conducted LCA and carbon footprint studies of their products, both of which will help in so doing, but in the long term, the research has indicated that the precast concrete industry will benefit from focusing on life-cycle resource efficiency through the use of recycled aggregates, reduction in energy use and sourcing of green energy, cement replacements or alternatives, reduction in water use and waste. This will certainly reduce the environmental impacts of the industry and other upstream associated embodied impacts. The EPD framework developed will further help in the communication of reliable, verifiable, accurate and certified information about the environmental credentials of precast concrete products and service in a coherent and consistent manner.

6.7 CRITICAL EVALUATION

On reviewing the content of this thesis, a number of observations can be made about the quality of the research in terms of scope, depth, quality and bias for example. This section provides an overview of some of the distinctive features of this research programme and some key limitations.

- Due to the economic recession experienced in the UK within the research timeframe, the programme of work was adjusted to reflect the industrial sponsors' needs. For instance, it would have been preferable to test the EPD framework within a company, but this was not possible, so the possible implementation was validated in a general way through an industry focus group, such that it could be implemented in the future.
- It might have been expected to see a quantified life-cycle assessment as part of this research. While LCA has been identified as an integral part of EPD development, the underpinning understanding of the indicators for the industry, how PS might manifest

itself and how an EPD scheme would be implemented were more germane to the aim and objectives of the work.

- It might also have been appropriate to expect the research to pursue a theme of reduction in cement use for precast concrete manufacture, but this is well-trodden ground and was outside the scope of the industrial sponsor's influence. That said, the pressure to reduce carbon emissions is unlikely to abate, so it would be understandable if subsequent studies chose to pursue that particular impact 'hot spot'.
- This research was conducted for the UK precast concrete industry and so is necessarily limited primarily to this domain, which could be perceived as rather restricted. It could be of benefit to other industries, although the results cannot directly be generalised. A straightforward translation would be to extrapolate the findings to other types of concrete production or to precast industries outside the UK. That said, the research also has a wider applicability beyond concrete, because numerous PS schemes, initiatives and programmes were analysed and studied.
- It would have been possible to adopt different research methods for certain stages, but the choices were made on sound reasoning given the time available, needs of the industry and requirements for the data collection in terms of the overarching objectives for the study. That said, in all instances, the subjects would probably have remained consistent (i.e. the key sustainability representatives from each manufacturer). The key group which was not included in the research was designers, owing to time restrictions, but this would be a worthwhile extension to the study.
- The small sample sizes in the survey, interviews and focus group could be said to be too small. However, the survey was conducted with the 12 precast concrete manufacturing companies that cover 66% of the precast concrete industry's total product output (in 2010) and the interviewees included both SMEs and the main multi-national companies within the industry. Hence, the sample sizes should be reliable.
- As with all industry-supported research, there will be a question of potential bias in the approach, focus or data. In this instance, the industrial sponsor is a federation and not a commercial entity, so is in a role of influence and support. For this reason, it had no reason to try to bias the research process. In addition, the academic supervisors for the study ensured that any research instruments were developed without bias in terms of leading questions etc.

6.8 CONTRIBUTION TO KNOWLEDGE IN THE SUBJECT AREA

The focus of the research has been product stewardship (PS), as applied within an industrial context. For this reason, the main contributions to knowledge fall within two areas. First the work has made a contribution to the literature on PS. The findings from this EngD research have contributed to the extant discourse by:

- identifying the key conceptual and structural components of PS for the precast industry;
- developing a PS process tree for the precast industry; and,
- developing four generic models for PS and identifying one that closely matches the precast industry.

Moreover, research on PS within the construction industry is very limited, especially the development of an industry-specific strategy, scheme or initiative as is presented here. So the second major contribution lies in the industrial application of the work. This research is the first to:

- Interpret key components of PS in a precast concrete context
- Develop and validate a precast concrete sector-specific EPD framework
- Suggested a LCM strategy to be developed for the UK precast concrete industry.

6.9 CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

6.9.1 CONCLUSIONS

Sustainability and sustainable construction have now become business imperatives and form an integral part of different organisations and government policies in the UK. PS has been identified as a subset of sustainability and one of the tools used by industry to mitigate environmental and social impacts of products by various stakeholders through a life-cycle approach. Many countries and corporate organisations have recorded business gains through the implementation of PS for example financial profits, improved ethical sourcing, corporate social responsibility etc. The UK precast concrete industry has shown that it can measure, analyse and improve its environmental performance. This can further be enhanced through the full implementation of an EPD scheme that communicates the industry's products environmental information. The Construction Product Regulations (CPR) that will come into force on 1st July, 2013 in European Union countries (including the UK) will serve as a main driver towards making companies embrace and advance the course of EPD implementation by precast concrete companies.

The EPD framework fills a gap within the existing industry initiatives on sustainability by providing a robust approach to the communication and reporting of reliable, verifiable and third party certified EPDs for precast concrete products and services. This research has found that in order to implement an EPD scheme for the precast concrete industry, the industry needs to set up a steering committee with the mandate of overseeing the general development, operation, implementation, running and review of an industry EPD scheme; appointment of programme operator; identifying and appointing a competent PCR consultant; establishing PCR; EPD training which includes EPD course approval and syllabus development; developing a LCA data or acquiring data from BRE; certification and accreditation of the EPD.

Further to this, elements of PS have been found to be evident within the precast concrete industry; the industry needs to develop a robust and coherent LCM strategy to provide a long-term vision and road map for the future. This will also compliment the current concrete industry 2020 strategy.

This EngD research has contributed to the current sustainability initiatives of the industry through the EPD framework development; identifying key industry impacts and provided suggestions impact mitigation strategies (such as; LCM, Design for sustainability and Design for environment; see figure 4.3) as means to manage and mitigate these impacts; analysis of the industry's KPI data between 2006- 2012, and identified the barriers and enablers to change within the industry.

6.9.2 RECOMMENDATIONS FOR THE INDUSTRY

Apart from testing, refining and implementing the draft EPD framework developed in this research, there are a few specific recommendations that are germane to the UK precast industry; these are listed below.

- The implementation of key components of PS identified through this research need to be explored further and tested within manufacturing companies. This will become easier to achieve as companies begin to engage with PS and EPDs and they develop a more critical stance on the details.
- The UK precast industry, through BPCF, should develop an overarching strategy on life-cycle management issues, such that it has a consensus on appropriate initiatives. This could follow the model set out in its sector sustainability strategy and lead to a charter scheme for example. The BPCF Sustainability Committee would be most suited to take the lead on such a programme.
- The upstream and manufacturing parts of the concrete industry need to develop a shared understanding of life-cycle impacts apropos cement. There is little that precast concrete manufacturers can do to offset the carbon emissions 'legacy' that their products inherit through the inclusion of CEM I apart from using alternative binders, such as CEM II. BPCF should work with its sister trade bodies to seek such an agreement, within the terms set out for PCR in BS EN 15804 and ISO 14025.

6.9.3 AREAS IDENTIFIED FOR FURTHER RESEARCH

This section identifies two specific opportunities that have emerged from this study and that would be suitable for further research, as described below.

The effectiveness of EPD implementation within the precast concrete industry. This EngD research has developed an EPD framework for the precast concrete industry. Further empirical research is needed to study and understand the efficiency, effectiveness and challenges experienced during implementation. Company case studies could be used to help identify the strengths and weaknesses of the framework and further provide information on improving the framework for better performance and service delivery.

A collaborative stakeholder responsibility matrix and mitigation tool. The research has shown that concrete's key life cycle stages involve multiple stakeholders and these stakeholders have varying levels of responsibilities which also include taking responsibility of negative environmental, social and economic impacts mitigation. The industry needs to understand how to apportion stakeholder responsibilities upstream and downstream the supply chain (a for example a robust, all inclusive and stakeholder participatory LCM strategy could be developed that includes all environmental, economic and social issues such as upstream and downstream impacts, concrete life span and cycle, impacts ownership, cost implications, legal issues, incentives by government through funding and research and development) with all

stakeholders involved), most especially with clients, manufacturers and the government. Further work is needed to develop a collaborative responsibility matrix, which should focus particularly on the manufacturer-designer relationship; BIM (Building Information Modelling) might present a suitable framework within which the outcomes of such matrix could be tested and delivered.

7. REFERENCES

1. Aliyu, A. A., Glass, J., Clarke, M.A., Elhag, H.K. and Price, A.D.F. (2009). The need for a product stewardship scheme to improve sustainability in the UK precast concrete industry. In: Ketola, T. (Ed), Responsible Leadership. Proceedings of the Corporate Responsibility Research (CRR) 2009 Conference, University of Vaasa:Vaasa (Finland), pp. 1-17. ISBN 978-9-52476-285-4.
2. Aliyu, A. A., Glass, J., Clarke, M.A., Elhag, H.K. and Price, A.D.F. (2012). Assessing the potentials of Product stewardship in the UK precast concrete industry. Proceedings of the International Conference on Concrete: In the Low Carbon Era, 9-11 July, 2012. University of Dundee: Dundee, pp.374 – 386.
3. Adams, G. (2010). 10 Principles of Responsible Product Stewardship. [Online] available at: http://www.greenbiz.com/blog/2010/07/30/10-principles-responsible-product-stewardship. [Accessed on 19th October, 2011].
4. Adams, W.M. (2006). The Future of Sustainability: Re-thinking Environment and Development in the Twenty-first Century. Report of the IUCN Renowned Thinkers Meeting, 29–31 January 2006. [Online] available at: http://cmsdata.iucn.org/downloads/iucn_future_of_sustanability.pdf.
5. Adetunji, I.O. (2006). Sustainable Construction: A web-based performance assessment tool. Loughborough University (EngD Thesis).
6. Aggregate Industries (2013). Life Cycle Analyzer; Environmental Assessment of Concrete. [Online] Available at: http://www.aggregate.com/pagefiles/10522/ai-report-c35-20mm-cem1-r2-wra.pdf/. Accessed on: 9th December, 2013.
7. Aïtcin, P. (2007). *Binders for durable and sustainable concrete*. Routledge Publishers. ISBN 0415385881, 9780415385886.
8. Anderson, J. and Thornback, J. (2012). A guide to understanding the embodied impacts of construction products. Construction Products Association.
9. Anderson, J., Shiers, D. and Steele, K. (2009). The Green Guide to Specification: BREEAM Specification. Fourth edition. ISBN-13: 978-1405119610.
10. Anon, 2001.Concrete and the environment, *Concrete Society* 35(8) pp.39-46.
11. Anthony, L., Brenda, M and McEvoy., T. (2009). *The Literature Review: Six Steps to Success*. Corwin Press, California. ISBN-10: 1412961351, 978-1412961356.
12. Armstrong, G. and Kotler, P. (2006). Marketing: an introduction, Eighth ed. Financial Times/Pearson Prentice Hall, Harrow.
13. Ayshin S. (2008). How can the construction industry contribute to sustainable development? a conceptual framework. *Sustainable Development*. Vol.10 (1002).
14. Bailey, I. (2003). New environmental policy instruments in the European Union: politics, economics, and the implementation of the packaging waste directive. Aldershot: Ashgate Publishing Ltd.
15. Baker, S. (2006). Sustainable Development; Routledge's introductions to environment series. Routledge: 1st edition.
16. Baker, M., J and Foy, A. (2008). Business and Management Research: How to Complete Your Research Project Successfully. Argyll: Westburn Publishers Ltd. ISBN-13: 978-0946433049.

17. BASF. (2010). Product Stewardship. [Online] Available at: http://www2.basf.us/corporate/ehs/product_stewardship.htm. [Accessed on: 11 February, 2010].
18. BASF (2013). BASF Life Cycle Analysis tool to support sustainable concrete solutions. [Online] Available at: http://www.basf-cc.co.uk/en/Sustainability/LifeCycleAnalyzer/Pages/default.aspx. Accessed on: 9th December, 2013.
19. BCA. (2006). Performance: a corporate responsibility report from the UK cements industry. British Cement Association.
20. Bennett, J. and Crudgington, A. (2003). Sustainable development: recent thinking and practice in the UK. Proceedings of the Institution of Civil Engineers, *Engineering Sustainability*, 156 ES1 (2003), pp. 27–32.
21. BERR. (2010).Packaging and Packaging Waste Directive 94/62/EC. [Online] Available at: http://www.berr.gov.uk/whatwedo/sectors/sustainability/packaging/page29072.html. [Accessed on: 1st March, 2010].
22. BERR. (2008). Strategy for Sustainable Construction. Department for Business, Enterprise and Regulatory Reform, London.
23. BERR. (2009). Strategy for Sustainable Construction - Progress Report. Department for Business, Enterprise and Regulatory Reform, London.
24. Bhatia, P. and Ranganathan, J. (2004). The Greenhouse Gas Protocol: A Corporate accounting and Reporting Standard, Revised edition, World Business Council for Sustainable Development (WBCSD). Washington DC.
25. BIBM. (2008). British Precast Concrete Federation. European Precast Book 2008, Galazzano: Bureau International du Béton Manufacturé.
26. Bijen, J., M. (2002).Environmental Information on Concrete, in Dhir, R. K., Dyer, T.D and Halliday, J. E. (eds.): *Proceedings of International Congress on Challenges of Concrete Construction: Sustainable Concrete Construction*, University of Dundee, Scotland, pp.57-67.
27. BSI. (2014). BES 6001 Responsible Sourcing of Construction Products. [Online]. Available at: http://www.bsigroup.com/en-GB/bes-6001-responsible-sourcing-of-construction-products/. Accessed on: 16th March, 2014.
28. BIS. (2010a). Low Carbon Construction; Innovation and Growth Team. [Online] Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/31773/10-1266-low-carbon-construction-IGT-final-report.pdf [Accessed on: 4th July, 2013].
29. BIS - Department for Business Innovation and Skills. (2010). EC Directive on Waste Electrical and Electronic Equipment (WEEE). [Online] Available at: http://www.berr.gov.uk/whatwedo/sectors/sustainability/weee/page30269.html. [Accessed on: 15th January, 2010].
30. BIS. (2010a). End of Life Vehicles. [Online] Available at: http://www.berr.gov.uk/policies/business-sectors/environmental-and-technical-regulations/environmental-regulations/end-of-life-vehicles. [Accessed on: 1st March, 2010].
31. BIS. (2012). Low Carbon Construction Action Plan. [Online] Available at: http://www.bis.gov.uk/policies/business-sectors/construction/low-carbon-construction-igt/low-carbon-construction-action-plan. Accessed on: 21st October, 2012.

32. BIS. (2013). Construction 2025: industrial strategy for construction - government and industry in partnership. [Online] Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/210099/bis-13-955-construction-2025-industrial-strategy.pdf. [Accessed on: 3rd July, 2013].
33. Blumberg, B., Cooper, D., R and Schindler, P. S. (2005). Business Research Methods. McGraw-Hill Higher Education, Berkshire. ISBN-10: 007710742X, ISBN-13: 978-0077107420.
34. BIS. (2012). Sustainable Construction. [Online]. Available at: http://webarchive.nationalarchives.gov.uk/+/http://www.bis.gov.uk/policies/business-sectors/construction/sustainable-construction. Accessed on: 14th November 2012.
35. BIS. (2010). *EC Directive on Waste Electrical and Electronic Equipment (WEEE).* Department for Business Innovation and Skills [Online] available at: http://www.berr.gov.uk/whatwedo/sectors/sustainability/weee/page30269.html. [Accessed on: 15th January, 2010].
36. BPCF. (2009). Sustainability Charter. [Online] Available at: http://www.britishprecast.org/publications/download-publications.php#sustainabilitycharterpack. [Accessed on: 26th July, 2009].
37. BPCF. (2011). Membership Prospectus. British Precast Concrete Federation Limited. [Online] Available at: http://www.britishprecast.org/documents/BPCFProspectusJune2011.pdf. [Accessed on: 10th January, 2013].
38. BPCF. (2013). About British Precast. [Online] Available at: http://www.britishprecast.org/aboutus/about-us.php. [Accessed on: 11th January, 2013].
39. BPCF Charter. (2014). The Precast Charter Scheme. [Online]. Available at: http://www.bpcfcharter.com/. Accessed on: 16th March, 2014.
40. Brady, K., Henson, P., and Fava. J, A. (1999). Sustainability, Eco -efficiency, Life-cycle Management, and Business Strategy. Environmental Quality Management. Vol.8 No. 3, pp.33-41.
41. British Precast. (2010). Sustainability Matters; Ecobuild update. British Precast, Leicester.
42. British Precast. (2010). CT2010. [Online]. Available at: http://www.britishprecast.org/documents/BPCFH-Snewsletter2.pdf. [Accessed on: 27th July, 2010].
43. British Precast and Construction News. (2008). Building Excellence in Precast; Sustainability, Health and Safety, Innovation and Projects, London: BPCF.
44. BRE (2005). Green Guide to Specification; BRE Materials Industry Briefing Note 3b: Normalisation. Available at: http://www.bre.co.uk/greenguide/files/NormalisationBriefingDocumentFinal.pdf.. [Accessed on: 14th November, 2013].
45. BRE (2000) Digest 446, "Assessing environmental impacts of construction: Industry consensus, BREEAM and UK Ecopoints. CRC Limited.
46. BRE. (2013). Environmental Profiles of Construction Products. [Online] Available at: http://www.bre.co.uk/filelibrary/greenguide/PDF/EP.CP.1.3_SD028-5_Environmental_Profiles_of_construction_products_Feb_2012.pdf. [Accessed on 8th July, 2013].

47. BRE Global. (2009). *BRE Environmental and Sustainability Standard; Framework Standard for the Responsible Sourcing of Construction Products*. Issue 2.0.pp.1-28. British Research Establishment.
48. BRE Global. (2009a). BRE Environmental and Sustainability (BES) Standard 6050. Methodology for Environmental Profiles of Construction Products: Product Category Rules for Type III environmental product declaration of construction products. BES 6050: Issues 1.0. Bracknell, IHS BRE Press.
49. BRE. (2012). Construction Products and CEN TC 350 Standards [Online] Available at: http://www.bre.co.uk/page.jsp?id=2747. Accessed on: 17th April, 2012.
50. BRE. (2010). Product Category Rules for Type III environmental product declaration of construction products to EN 15804:2012. Available [Online] at: http://www.bre.co.uk/filelibrary/Materials/BRE_EN_15804_PCR.PN514.pdf. Accessed on: 9th March, 2014.
51. BRE. (2014). Ecopoints. Available [Online] at: http://envestv2.bre.co.uk/help/index.jsp?pageID=36. Accessed on: 29th August, 2014.
52. British Precast and Construction News. (2008). *Building Excellence in Precast; Sustainability, Health and Safety, Innovation and Projects*, London: BPCF.
53. British Precast. (2013). Sustainability Matter 2013 (October update). [Online]. Available at: http://www.britishprecast.org/documents/BPSustainabilityMattersOct2013Update.pdf. Accessed on: 16th March, 2014.
54. British Precast. (2014). About Sustainability. [Online]. Available at: http://www.britishprecast.org/sustainableprecast/about-sustainability.php. Accessed on: 16th March, 2014.
55. Brundtland, H. (1987). Our Common Future. Oxford: Oxford University Press, for the World Commission on Environment and Development (WCED).
56. Bruijn, Theo de., in Visser, W., Matten, D., and Pohl, M. (2007). The A to Z of corporate social responsibility: a complete reference guide to concepts, codes and organisations. An ICCA publication. John Wiley and Sons, 2007. ISBN 0470723955, 9780470723951.
57. Bryman, A. and Bell, E. (2007). *Business Research Methods*. Oxford University Press, Oxford.Second Edition. ISBN – 0-1992-8498-9.
58. Bryman, A. (1988). Quantity and Quality in Social Research. Psychology Press. ISBN 0415078989.
59. Bryman, A. and Bell, E. (2007). Business Research Methods. Oxford University Press, Oxford.Second Edition. ISBN – 0-1992-8498-9.
60. Bryman, A. and Bell, E. (2011). Business Research Methods 3e. Third Edition. London: Oxford University Press.
61. BS 8555. (2003). Environmental management systems. Guide to the phased implementation of an environmental management system including the use of environmental performance evaluation. London: British Standard Institution.
62. BSI. (2003). BS 8555 Environmental management systems. Guide to the phased implementation of an environmental management system including the use of environmental performance evaluation. British Standard Institution: London.
63. BSI. (2009). BS 8902; Responsible sourcing sector certification schemes for construction products specification. London: British Standard Institution.

64. BS EN 15978:2011(2011). Sustainability of construction works — Assessment of environmental performance of buildings — Calculation method.. London: British Standards Institutions (BSI).
65. BSI. (2014). EN 15804:2012+A1:2013 - Sustainability of construction works — Environmental product declarations — Core rules for the product category of construction products. London: British Standard Institution.
66. BSI. (2014a). BES 6001 Responsible Sourcing of Construction Products. [Online]. Available at: http://www.bsigroup.com/en-GB/bes-6001-responsible-sourcing-of-construction-products/. Accessed on: 16th March, 2014.
67. BS EN 15804. (2012). Sustainability of construction works. Environmental product declarations. Core rules for the product category of construction products. London: British Standard Institution. (Now withdrawn and superseded by EN 15804:2012+A1:2013).
68. Burke, S and Gaughran, W.F. (2006) Robotics and Computer-Integrated. Manufacturing 22, pp. 566–575.
69. Carbon Trust. (2010). Carbon Foot printing. [Online] available at: http://www.carbontrust.co.uk/cut-carbon-reduce-costs/calculate/carbon-footprinting/pages/carbon-footprinting.aspx. [Accessed on: 26th October, 2010].
70. Carlton, R. and Thompson, H. (2009). Product Stewardship - Is there a role for better collaboration? *Outlooks on Pest Management*, Volume 20 (3), pp. 126-127(2).
71. Carter, C.R. and Rogers, D. S. (2008). A framework of sustainable supply chain management: moving toward new theory. *International Journal of Physical Distribution & Logistics Management*. Vol. 38 (5), pp. 360 - 387.
72. CBI. (2009). Future proof: preventing your business for a changing climate. [Online] Available at: http://climatechange.cbi.org.uk/uploaded/CBI_Future%20proof_Preparing%20your%20business%20for%20a%20changing%20climate.pdf. Accessed on: 27th October, 2010.
73. CPA. (2007). Delivering sustainability; the contribution of construction products. Construction Product Association. London.
74. CEMBUREAU. (2012). Environmental Product Declaration. [Online] Available at: http://www.cembureau.be/topics/sustainable-construction/environmental-product-declaration. Accessed on: 19th November, 2012.
75. CEMBUREAU. (2012a). CEMBUREAU Environmental Product Declaration for Cement; user guide. [Online] Available at: http://www.cembureau.be/sites/default/files/02%20EPD%20User's%20Guide%20FINAL%20(10%2009%202008).pdf. Accessed on: 19th November, 2012.
76. CEMEX. 2012. Sustainability in action; CEMEX UK Operations. [Online] Available at: http://www.cemex.co.uk/su/pdf/Sustainability_Update_1106.pdf. Accessed on: 29th November, 2012.
77. CIB. (1998). Sustainable Development and the future of construction; A comparison of visions from various countries. CIB Working Commission W82 "Future Studies in Construction". CIB Report Publication 225. ISBN 90-6363-011-5.
78. CICE. (2014). *What is the Engineering Doctorate (EngD)?* [Online] Available at: http://www.lboro.ac.uk/research/cice/engdprogramme/. [Accessed on: 11th January, 2014.].
79. CIRIA. (2001). Sustainable Construction: company indicators C563. ISBN 0860175634.

80. Clarke, M. A. and Glass, J. (2008). Forget the Concrete: It's the added Value that counts. Proceedings of the International Conference on Concrete: Construction's Sustainable Options, 8-10 July, 2008. University of Dundee: Dundee, pp.1-8.
81. CIOB. (2009). Sustainability and Construction. Chartered Institute of Building [Online] available at: http://www.ipbassociates.com/uploads/Sustainability_construction_1287073859.pdf. [Accessed on: 29th January, 2009].
82. CISFC. (2008). Concrete Industry Guidance Document to support BRE Global BES 6001. Issue 1. Concrete Industry Sustainable Construction Forum [Online] Available at: www.sustainableconcrete.org.uk. [Accessed on: 8th July, 2009].
83. CISCF. (2008). Concrete Industry Sustainable Construction Strategy. 2008. Available online at: http://sustainableconcrete.org.uk/concrete_sustainable_strategy.aspx. [Accessed on: 26th October, 2010].
84. Clarke, M. (2003). *British Precast - a Profile*. Concrete for the Construction Industry; Precast focus. Vol. 37, Part 11, p. 6-7. The Concrete Society: London. ISSN 0010-5317.
85. Clarke, M. A. and Glass, J. (2008). *Forget the Concrete: It's the added Value that counts.* Proceedings of the International Conference on Concrete: Construction's Sustainable Options, 8-10 July, 2008. University of Dundee: Dundee, pp.1-8.
86. Climatedec. (2012). International EPD (R) System. [Online] Available at: http://www.climatedec.com/about/Backgound/The-International-EPDRsystem/. [Accessed: 10th February, 2012].
87. Concrete Centre. (2008). Concrete Sustainability. [Online] (Updated 13th November, 2008) available at: http://www.concretecentre.com/main.asp?page=155. [Accessed on: 27th July, 2009].
88. Concrete Centre. (2009). The Concrete Industry Sustainability Performance Report; first report. [Online] available at: http://www.sustainableconcrete.org.uk/PDF/SCS%20Performance%20Report%20FINAL.pdf. [Accessed on: 7th December, 2012].
89. Concrete Centre. (2009). *Benefits of Concrete*. [Online] available at: http://www.concretecentre.com/main.asp?page=13. [Accessed on: 27th July, 2009].
90. Concrete Society. (2001) Concrete and the environment, Concrete Society 35(8) p.39-46.
91. Concrete Society. (2014). Available [Online] at: http://www.concrete.org.uk/fingertips_nuggets.asp?cmd=display&id=669. Accessed on: 29th August, 2014.
92. Conrad, L and Lagerstedt, J. (2011). Design and The Ten Golden Rules: generic advice for merging environmental aspects into product development. Journal of Cleaner Production. Vol. 14, p.1396–1408.
93. Collis, J. and Hussey, R. (2003). Business Research. Basingstoke: Palgrave Macmillan.
94. Collins, F. and J.G. Sanjayan. (2002). The challenge of the cement industry towards the reduction of greenhouse emissions. Proceedings of the International Association of Bridge and Structural Engineers (IABSE) Conference, September, Melbourne.
95. Creswell. J. W. (2007). Qualitative Inquiry and Research Design: choosing among Five Approaches. London: Sage.

96. Creswell. J.W. (2008). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches. Thousand Oaks. SAGE Publications.
97. Cruickshank, H. J. and Fenner, R. A. (2007). The evolving of engineers: Towards sustainable development of the built environment. *Journal of International Development*, Vol. 19 (1), p.111–121.
98. Coglan, D and Brannick, T. (2010). Doing Action Research in Your Own Organization. Sage Publication: London.
99. CPA. (2007). *Delivering sustainability; the contribution of construction products.* Construction Product Association. London.
100. CPA. (2009). The Construction Products Industry. Construction Product Association website. [Online] Available at: http://www.constprod.org.org.uk. [Accessed on: 21st June, 2009].
101. CSI. (2012). Cement Sustainability Initiative; WBCSD. Available [Online] at: http://csiprogress2012.org/templates/rt_voxel/CSI%20Progress%20Report_20120530.pdf. [Accessed on: 9th March, 2014].
102. Curkovic, S. and Sroufe, R. (2011). Using ISO 14001 to promote a sustainable supply chain strategy, *Business Strategy and the Environment*, 20(2), 71-93.
103. Curkovic, S., Sroufe, R., and Melnyk, S. A. (2005). Identifying the factors which affect the decision to attain ISO 14001. *Journal of Energy*, 30(8), pp. 1387– 1407.
104. Davis J. B. (1996). Product Stewardship and the Coming Age of Take-Back. Cutter Information Corp. 1996. ISBN 1574840304.
105. DCLG. (2008). *Sustainable Development Action Plan 2007-2008*. Department for Communities and Local Government, London.
106. Denzin, N. and Lincoln, Y. (1998). Collecting and Interpreting Qualitative Materials, Sage, Thousand Oaks: CA.
107. Dawson, C. (2002). Practical Research Methods: A User-friendly Guide to Mastering Research Techniques and Projects. Oxford: How to Books Limited.
108. DCLG. (2008). *Sustainable Development Action Plan 2007-2008*. Department for Communities and Local Government, London.
109. DEFRA. (2010). Producer responsibility [Online] Available at: http://www.defra.gov.uk/environment/waste/producer/index.htm. [Accessed on: 19th August, 2010].
110. DEFRA. (2008). UK climate change sustainable development indicator: 2006 greenhouse gas emissions, final figures - Statistical Release. [Online] Available at: http://www.defra.gov.uk/News/2008/080131a.htm. [Accessed on: 20th February, 2010].
111. DEFRA. (2005). *One future – different paths; the UK's shared framework for sustainable development*. Department of Environment, Food and Rural Affairs, London.
112. DEFRA. (1999). *Securing the future; the UK Governments sustainable development strategy*. Department of Environment, Food and Rural Affairs, London.
113. Dell. (2010). Dell corporate website [Online] Available at: http://www.dell.com/content/topics/global.aspx/about_dell/values/sustainability/environment/product?c=us&l=en. [Accessed on 21st January, 2010].
114. DeSimone, L., D and Popoff, F. (2000). Eco-Efficiency: The Business Link to Sustainable Development. MIT Press, 2000. ISBN 0262541092.

115. DETR. (1999). *A Better Quality of Life: a strategy for sustainable development in the UK*. Department of the Environment, Transport and the Regions, London.
116. DETR. (1994). Sustainable Development: The UK Strategy. Department of the Environment, Transport and the Regions, London. ISBN 010124262X.
117. DETR. (1998a). Opportunities for Change: Sustainable Construction. Department of the Environment, Transport and the Regions, London.
118. DETR. (1998b). Rethinking Construction: The Report of the Construction Task Force. Department of the Environment, Transport and the Regions, London. ISBN 1851120947.
119. DTI. (2004). Sustainable Construction Brief 2. Department of Trade and Industry, London.
120. DETR. (1999). *A Better Quality of Life: a strategy for sustainable development in the UK*. Department of the Environment, Transport and the Regions, London.
121. DG Environment. (2002). Evaluation of Environmental Product Declaration Schemes, final report.
122. Dillon, P. and Baram, M.S. (1991). Forces shaping the development and use of product stewardship in the private sector. In: Conference on 'The Greening of Industry'.
123. Ding, G.K.C. (2008). Sustainable construction; the role of environmental assessment tools. *Journal of Environmental Management*. Vol. 86 (3), pp. 451–464.
124. Donna, J., W. J.M. Logsdon and Patsy G. (2006). Global business citizenship: a transformative framework for ethics and sustainable capitalism .Edition illustrated. M.E. Sharpe. ISBN 0765616270, 9780765616272
125. Dow Chemical. (2010). Our Company [Online] Available at: http://www.dow.com/ [Accessed on: 1st March, 2010].
126. Dow. (2012). Product Safety. [Online] available at: http://www.dow.com/productsafety/overview/glossary2.htm. Accessed on: 30th November, 2012.
127. Dow Chemical. (2009). Our Company, [Online] available at: http://www.dow.com/about/ [Accessed on: 2nd February, 2009].
128. Dow Chemical. (2010). Our Company. [Online] Available at: http://www.dow.com/ [Accessed on: 1st March, 2010].
129. Dully, S., Ulbricht., C. Lückefett, H., Westkämper E.(Eds.). (2009). National Registration for Producers of Electronic Waste. Springer Berlin Heidelberg. ISBN 9783540927457.
130. DuPont. (2010).Our Company [Online] Available at: http://www2.dupont.com/Our_Company/en_US. [Accessed on: 1st March, 2010].
131. D4S. (2007). Design for Sustinability; a practical approach for Developing Economies. UNEP and Delft University of Technology. [Online]. Available at: http://www.d4s-de.org/manual/d4stotalmanual.pdf. [Accessed on 12th March, 2014].
132. Easterby-Smith, M., Thorpe, R. and Lowe, A. (1991). *Management Research: An Introduction*. 1st edition. SAGE Publications. London. ISBN 0-8039-8392-1.
133. EC. (2010). Waste- End of Life Vehicles [Online] Available at: http://ec.europa.eu/environment/waste/elv_index.htm; [Accessed on: 1st March, 2010].
134. EC. (2008). Environment fact sheet: Sustainable consumption and production — a challenge for us all. European Commission. [Online] available at:

http://ec.europa.eu/environment/eussd/pdf/brochure.pdf. [Accessed on: 28th October, 2010].

135. EC. (2010).Recast of the WEEE and RoHS Directives proposed in 2008. European Commission [Online] Available at: http://ec.europa.eu/environment/waste/weee/index_en.htm. [Accessed on: 15th January, 2010].
136. Elhag, H. and Richards, N. (2013). Hafiz.elhag@britishprecast.org. Current total precast concrete industry employees (2013). 05 July 2013 13:07.
137. European Commission. (2010a). Waste- End of Life Vehicles. EC. [Online] available at: http://ec.europa.eu/environment/waste/elv_index.htm; [Accessed on: 1st March, 2010].
138. EC. (2010b). Environment; Waste - Packaging Waste. European Commission. [Online] available at: http://ec.europa.eu/environment/waste/packaging_index.htm; [Accessed on: 1st March, 2010].
139. European Commission. (2014). Construction Products Regulation. Available [Online] at; http://ec.europa.eu/enterprise/sectors/construction/legislation/index_en.htm. Accessed on: 15th March, 2014.
140. Eden, C. and Huxham, C. (1996). Action Research for Management Research, *British Journal of Management*. Vol.7 (1), pp. 75-86.
141. EHPC. (2012). Product stewardship. [Online] available at: http://www.ephc.gov.au/stewardship; [Accessed on: 7th December, 2012].
142. Elchalakania, M., Alyb, T. and Abu-Aishehc, E. (2014). Sustainable concrete with high volume GGBFS to build Masdar City in the UAE. *Case Studies in Construction Materials*. Volume 1, pp. 10–24.
143. Elhag, H. (2013). Current precast concrete industry production – Email 5th July, 2013, hafiz.elhag@britishprecast.org.
144. Elhag, H., Glass, J., Gibb, A.G.F., Clarke, M., Budge, C. and Bailey, G.K. (2008). Implementing Environmental Improvements in a Manufacturing context: a structured approach for the precast concrete industry. *International Journal of Environmental Technology and Management*, Vol. 8(4), pp.369-384.
145. Elliot. K. S. (2002). Precast Concrete Structures. Oxford; Elsevier. ISBN 0750650842.
146. EPA. (2013). Product Stewardship. [Online] Available at: http://www.epa.gov/epawaste/conserve/tools/stewardship/index.htm.[Accessed on: 11th January, 2013].
147. Epstein, M. J. (2008). Making sustainability work: best practices in managing and measuring corporate social, environmental and economic impacts. Berrett-Koehler Publishers Inc. San Francisco. ISBN 1576754863.
148. Erbschloe, M. (2003). Socially responsible IT management, Enterprise Computing Series. Edition illustrated, Digital Press, ISBN 1555582907.
149. Erlandsson, J. and Tillman, A-M. (2009). Analysing influencing factors of corporate environmental information collection, management and communication. *Journal of Cleaner Production*, Vol. 17, pp. 800–810.
150. Envirodec. (2012). EPD® system – a programme for type III environmental declarations with an international applicability. Also known as the Swedish EPD-system. [Online] Available at: www.environdec.com; [Assessed on: 11th February, 2012].

151. Envirodec. (2012a). Ready-Mix Concrete Environmental Declaration. Available online at: http://gryphon.environdec.com/data/files/6/7503/epd108e.pdf. Accessed on: 28th December, 2012.
152. Fellows, R. and Liu, A. (2003). Research Methods for Construction. 2nd edition. Blackwell, Oxford. ISBN 0-632-06435-8.
153. Fiksel, J. (2009). Design for Environment: A Guide to Sustainable Product Development. The McGraw-Hill. USA. ISBN: 9780071605564.
154. Flick, U. (2009). An Introduction to Qualitative Research. Fourth edition. SAGE Publishers. ISBN 1847873243, 9781847873248.
155. Fava, J., Baer, S. and Cooper, J. (2011). Green(er) product standard trends in North America. *Journal of Industrial Ecology*, Vol.15, pp. 9-12.
156. Fet, A.M., Skaar, C. and Michelsen, O. (2009). Product category rules and environmental product declarations as tools to promote sustainable products: experiences from a case study of furniture production. *Clean Technology and Environmental Policy*, Vol. 11, pp. 201–207.
157. Fiksel, J. (2009). Design for Environment: A Guide to Sustainable Product Development. The McGraw-Hill. USA. ISBN: 9780071605564.
158. Fink, A. (1998). Conducting research literature reviews: from paper to internet. Thousand Oaks: Sage; 1998.
159. Flower D. J. M. and Sanjayan, J. G. (2007). Green House Gas Emissions due to Concrete Manufacture. *International Journal of LCA*, 12 (5) 282-288.
160. Friedman, A., L and Miles. S. (2006). Stakeholders: theory and practice. Edition illustrated. Oxford University Press. ISBN 0199269874, 9780199269877.
161. Gill, J. and Johnson, P. (2010). *Research Methods for Managers*. Sage Publications Ltd; Fourth Edition. London. ISBN-10: 1847870945.
162. Given. L. M. (2007). The SAGE Encyclopaedia of Qualitative Research Methods. (Two Volume Set). London: Sage.
163. Goddard, W. and Melville, S. (2004). Research Methodology: An Introduction. Lansdowne: Juta and Company Ltd. ISBN9780702156601.
164. Gramatyka, P., Nowosielski, R. and Sakiewicz, P. (2007), Recycling of waste electrical and electronic equipment. Journal of Achievements in Materials and Manufacturing Engineering (JAMME) Vol. 20, Issues 1-2, January-February 2007. [Online] Available at: http://www.journalamme.org/papers_vol20/1530S.pdf. [Accessed on: 24th January, 2010].
165. Gubrium, J. and Holstein, J. (2001) (eds). Handbook of Interview Research. SAGE Publications: London.
166. Haigh, R. (2008). Interviews; A negotiated partnership", Knight, A. and Ruddock, L., Advanced Research Methods in the Built Environment, Wiley- Blackwell, Oxford, p.111-121.
167. Hart, C. (2007). Doing a Literature Review: Releasing the Social Science Research Imagination. London: Sage.
168. Hart, S. L. (2007). Capitalism at the crossroads: aligning business, earth, and humanity.
169. Hart, S.L. and Milstein, M, B. (1999). Global Sustainability and the Creative Destruction of Industries. *Sloan Management Review*, Vol. 41, No.1, pp. 1-23.

170. Hart, S.L., (1997). Beyond Greening: Strategies for a Sustainable world. *Harvard Business Review*. Jan.-Feb. 1997, pp. 66-76.
171. Hart, S.L., (1995). A natural-resource based view of the firm. *Academy of Management Journal*, Vol. 37 pp.986-1014.
172. Hart, S. L and Milstein, M.B. (2003).Creating sustainable value. *Academy of Management Executive*, Vol. 17, No. 2, pp.56-69. [Online] available at: http://www.stuartlhart.com/sites/stuartlhart.com/files/creatingsustainablevalue.pdf. [Accessed on 6th March, 2014].
173. Hennink, M., Hutter, I and Bailey, A. (2010). Qualitative Research Methods. London: SAGE.
174. Hennink, M., Hutter, I. and Bailey, A. (2011). Qualitative Research Methods. London: SAGE. ISBN 1412922259.
175. Hill, M. K. (2010). Understanding Environmental Pollution. Third edition. Cambridge University Press. ISBN 0521736692.
176. Henriques, A. (2001). Sustainability. A manager's guide. British Standards Institution, London. ISBN 0 580 33312 4.
177. Hewlett Packard. (2008). Global Citizenship Report. HP. [Online] available online at: http://www.hp.com/hpinfo/globalcitizenship/gcreport/envsustainability.html; [Accessed on: 19th February, 2010].
178. Hewlett Packard. (2010). Design for Environment. HP. [Online] available at: http://www.hp.com/hpinfo/globalcitizenship/environment/productdesign/design.html; [Accessed on: 22nd January, 2010].
179. HM Treasury. (2013). Infrastructure Carbon Review. Available [Online] at: http://www.cic.org.uk/publications/ . Accessed on: 9th March, 2014. ISBN 978-1-909790-44-5.
180. Holton, I. (2005). *Sustainability Matters; 1st Annual progress report from the Precast Industry*, BPCF, Leicester: British Precast, December, 2005, p.1-6.
181. Holton I., Glass J., Price A. (2010). Managing for sustainability: findings from four company case studies in the UK precast concrete industry. *Journal of Cleaner Production*.Vol.18, pp.152-160.
182. Holton, I. 2009. *Developing a sector sustainability strategy for the UK precast concrete industry*. Loughborough University (EngD thesis).
183. Holton, I, Glass, J, and Price, A. (2008). Developing a Successful Sector Sustainability Strategy: Six Lessons from the UK Construction Products Industry. *Corporate Social Responsibility and Environmental Management*, Vol.15, pp. 29-42.
184. Holton, I. (2007). Sustainability White Paper: Towards a more sustainable precast industry. [Online] available at: http://www.britishprecast.org/documents/WhitePaper_A5_8pp_LR.pdf; [Accessed on: 18th October, 2010].
185. Hopwood, B., Mellor, M. and O'Brien, G. (2005). Sustainable development: mapping different approaches. Sustainable Development, Vol. 13, pp.38–52.
186. Horne, R., Verghese, K. and Grant, T. (2009). Life cycle assessment: principles, practice, and prospects. Csiro Publishing. Collingwood.

187. HSE. (2009). Health and Safety Commission (HSC). Case study; Revitalising Health and Safety. [Online] available at: http://www.hse.gov.uk/revitalising/casestudyconcrete.pdf; [Accesses 13th January, 2009].
188. Humphreys, K. and M. Mahasenan. (2002). Climate Change in *Toward a Sustainable Cement Industry*. Battelle: World Business Council for Sustainable Development.
189. IBM. (2010), Corporate website. [Online] available at: http://www.ibm.com/ibm/us/en/. [Accessed on: 22nd January, 2010].
190. IBU. (2014). UK Average Portland Cement Mineral Products Association (MPA) UK. IBU - Institut Bauen und Umwelt e.V.Germany. [Online] available at: www.bau-umwelt.com/ https://epd-online.com . [Accessed on: 11th March, 2014].
191. IEA. (2010). C02 Emissions from Fuel Combustion; Highlights, 2010 edition. International Energy Agency (IEA). Available at: http://www.iea.org/co2highlights/ co2highlights pdf.
192. ICCA. (2008). Responsible Care Status Report. [Online] Available at: http://www.icca-chem.org/ICCADocs/Status_Report_2008.pdf.[Accessed on: 10th January, 2013].
193. ICCA. (2009). Responsible Care- Status Report. Status Report. [Online] Available at: www.responsiblecare.org/.../RC%20REPORT%2017-12spreadsint.pdf. [Accessed on: 21st February, 2010].
194. ICCA. (2010). Global Chemical Industry Reports Product Stewardship Progress to ICCM-2; Looks Forward to Further Accomplishments in Years Ahead. International Council of Chemical Associations. [Online] Available at: http://www.icca-chem.org/en/Home/News-and-press-releases/News-Archive/2009/Global-Chemical-Industry-Reports-Product-Stewardship-Progress-to-ICCM-2-Looks-Forward-to-Further-Accomplishments-in-Years-Ahead--/. [Accessed on: 26th January, 2010].
195. Ingwersena, W.W and Martha J. Stevenson, M.J. (2012). Can we compare the environmental performance of this product to that one? An update on the development of product category rules and future challenges toward alignment. *Journal of Cleaner Production*.Vol.24, pp. 102–108.
196. ISO. (2010). ISO 14025: Environmental labels and declarations. Type III environmental declarations. Principles and procedures. International Standards Organisation.
197. ISO. (2007). ISO 21930: Sustainability in building construction — Environmental declaration of building products. International Standards Organisation.
198. ISO. (2006). ISO 14025: Environmental labels and declarations. Type III environmental declarations. Principles and procedures. International Standards Organisation.
199. ISO. (2006). ISO 14044: Environmental management – Life cycle assessment – Requirements and guidelines, International Organisation for Standardisation (ISO), Geneve.
200. ISO. (2004). ISO 14001: Environmental Management Systems (EMS) – Requirements with guidance for use. International Organisation for Standardization, Geneva, Switzerland.
201. ISO. (2001). ISO 14020: Environmental labels and declarations - General principles. International Standards Organisation.

202. ISO. (1999a). 14021: Environmental labels and declarations - Self-declared environmental claims (Type II environmental labelling). International Standards Organisation.
203. ISO. (1999). 14024: Environmental labels and declarations - Type I environmental labelling - Principles and procedures. International Standards Organisation.
204. Jankowicz, A.D. (2005). Business Research Projects. Thomson Learning; Chapman and Hall: London.
205. Jesson, J., Matheson, L.,andLacey, F.M. (2011). Doing Your Literature Review: Traditional and Systematic Techniques. London: Sage; ISBN 1848601530.
206. JEMAI. (2012). Eco-Leaf; Environmental Declaration. [Online] Available at: http://www.jemai.or.jp/english/ecoleaf/pdf/ecoleaf_e.pdf. Accessed: 10th February, 2012.
207. Johnen, B, Foster, L and Thomas, M. (2000). Stewardship in the Agrochemical Industry. Zeneca Agrochemicals. [Online] Available at: http://www.rsc.org/delivery/_ArticleLinking/DisplayArticleForFree.cfm?doi=b006246o&JournalCode=PO. [Accessed on: 13th July, 2009].
208. Jamet, S. and Corfee-Morlot, J. (2009). Assessing the Impacts of Climate Change: A Literature Review. Economics Department Working Paper No. 691. OECD. [Online]. Available at: http://search.oecd.org/officialdocuments/displaydocumentpdf/?doclanguage=en&cote=eco/wkp(2009)32. [Accessed on: 12th March, 2014].
209. Jonathan, K. V. L. (2005). Product Stewardship. *Scrap*. Vol. 62, no. 1, pp. 69-74. Jan.-Feb. 2005.
210. Jorgensen, T., H. (2008). Towards more sustainable management systems: through life cycle management and integration. Journal of Cleaner Production, Vol.16, pp.1071-1080.
211. Kibert, C. J. (2013). Sustainable Construction: Green Building Design and Delivery. Hoboken: John Wiley and Sons. ISBN-10: 0470904453.
212. Kleindorfer, P.R., Singhal, K and van Wassenhove, L.N. (2005). Sustainable operations management. *Production and Operations Management*. Vol. 14 (4), pp. 482–492.
213. Knight, A and Ruddock, Les. (Eds.) (2009). Advanced Research Methods in the Built Environment. London: John Wiley & Sons. ISBN 144430951X.
214. Kodak. (2012). Product stewardship. [Online] Available at: http://www.kodak.com/ek/US/en/Global_Sustainability/Health_Safety_and_Environment/Product_Stewardship.htm. [Accessed on: 2nd December, 2012].
215. KPI Working Group (2000), "KPI Report for the Minister for Construction", Department of the Environment, Transport and the Regions, London, January 2000.
216. Kreith, F. and Tchobanoglous, G. (2002). Handbook of solid waste management. McGraw-Hill Professional. 2nd edition. ISBN 0071356231.
217. Kvale, S. (1996) InterViews: An Introduction to Qualitative Research Interviewing, Sage, Thousand Oaks, CA.
218. Kylakorpi, L., Bodlund, B. and Setterwall, C. (2007). LCA – A basis for environmental stewardship in the power industry, The Society of Environmental Toxicology and Chemistry.
219. Landon T. (2003). 13 steps to certifi cation in less than a year. Quality Progress 36 (3), pp. 32–41.

220. Lambert, A. J. D. and Gupta S. M. (2005). Disassembly modeling for assembly, maintenance, reuse, and recycling- The St. Lucie Press series on resource management. CRC Press. ISBN 1574443348.
221. Lapan, S. D., Quartaroli, M. T. and Riemer, F.J. (2011). Qualitative Research: An Introduction to Methods and Designs (Research Methods for the Social Sciences. San Francisco: John Wiley & Sons.
222. Levitt, M. (2007). Precast concrete: materials, manufacture, properties and usage. Second edition. Taylor and Francis, London. ISBN 041526846X.
223. Lewis. H. (2005). Defining product stewardship and sustainability in the Australian packaging industry. *Environmental Science and Policy*. Vol.8 (1), pp. 45-55.
224. Linton, J. D., Klassen, R. and Jayaraman, V. (2007). Sustainable supply chains: An introduction. *Journal of Operations Management*. Vol. 25 (6), pp.1071 - 1074.
225. Lozano, R. (2008). Envisioning sustainability three-dimensionally. *Journal of Cleaner Production*. Vol.16 (17), pp. 1838–1846.
226. Lozano, R., and Huisingh, D. (2011) Inter-linking issues and dimensions in sustainability reporting, *Journal of Cleaner Production*, Vol. 19, pp. 99-107.
227. Lippmann, M. (2009). Environmental Toxicants: human exposures and their health effects. 3rd edition, illustrated. Wiley- Interscience. ISBN 0471793353.
228. Lippmann, M. (2000). Environmental toxicants: human exposures and their health effects. 2nd edition, illustrated. John Wiley and Sons. ISBN 0471292982.
229. Madu, C., N. (2007). Environmental planning and management. Imperial College Press, 2007. ISBN 1860946712.
230. Manzini, R., Giuliano N., Massimiliano O. and Emanuele P. (2006). Assessing Environmental Product Declaration Opportunities: a Reference Framework. Business Strategy and Development 15 (2) pp. 118–134.
231. Malhotra, V.M. (1988). Use of Fly Ash, Slag and Condensed Silica Fume in North America and Europe. W.G. Ryan (Ed.), Proceedings of Concrete Workshop 88. International Workshop on the Use of Fly Ash, Slag, Silica Fume and other Siliceous Materials in Concrete, July 4–6, Sydney, Australia (1988), pp. 23–55.
232. Maxim, P.S. (1999). Quantitative Research Methods in the Social Sciences. ISBN-13: 978-0195114652.
233. Maxwell, J. and Loomis, D. (2002). Mixed methods design: An alternative approach. In A. Tashakkori& C. Teddlie (Eds.), Handbook of mixed methods in social and behavioural research, pp. 241–271. Thousand Oaks, CA: Sage.
234. Maylor, H. and Blackmon, K. (2005). Researching Business and Management: A Roadmap for Success. Palgrave Macmillan.
235. McKerlie, K, Knight., N and Thorpe., B. (2006). Advancing Extended Producer Responsibility in Canada. Journal of Cleaner Production, Vol. 14. 2006. pp. 616 - 628.
236. Meberatu, D. (1998). Sustainability and sustainable development: Historical and conceptual review. *Environmental Impact Assessment Review*. Vol. 18 (6), pp. 493-520.
237. Mehata, P.K. and Monteiro, P.J.M. (2014). Concrete and the Environment - Concrete: Microstructure, Properties, and Materials.. The University of California, Berkeley. [Online]. Available at:

http://www.ce.berkeley.edu/~paulmont/CE60New/Concrete%20and%20the%20Environment.pdf. Accessed on: 14th March, 2014.

238. Merlot, R. (1998). Product Stewardship: The Case of Digital Equipment Corporation. In Kostecki, Michel (Ed.). The Durable Use of Consumer Products New Options for Business and Consumption. Springer Publishers. ISBN 978-0-7923-8145-7.
239. Meredith, J. (1993). Theory building through conceptual methods. *International Journal of Operations & Production Management*, Vol.13 (5) (1993), pp. 3–11.
240. Microsoft. (2010). Microsoft Corporation "Annual Report 2009". [Online] available at: https://www.microsoft.com/msft/reports/ar09/10k_fh_fin.html. [Accessed on: 22nd January, 2010].
241. MFE. (2010). Ministry for Environement, ManatūMōTeTaiao, New Zealand. [Online] available at: http://www.mfe.govt.nz/issues/sustainable-industry/initiatives/product-stewardship/index.html. [Accessed on: 1st March, 2010].
242. Motorola. (2010). Mortorolla corporate website.[Online] available at: http://www.motorola.com/Consumers/US-EN/GLP [Accessed on: 15th January, 2010].
243. Morgan, D.J. (1997). Focus Group as Qualitative Research, Second Edition, Sage: London.
244. MPA British Precast. (2013). British Precast Annual Review. [Online]. Available at: http://www.britishprecast.org/publications/documents/BPCONCRETEANNUALREVIEWUSE-cp-email.pdf. [Accessed on; 16th March, 2014].
245. MPA. (2014). Mineral Products Association; Homepage. [Online]. Available at: http://www.mineralproducts.org/index.php. [Accessed on: 18th May, 2014].
246. Murray, M. and Langford, D. (2003). Construction Reports 1944-98. Publishers: Wiley Blackwell. ISBN-10: 0632059281.
247. National Floor Trends (2012). Using EPDs for Better Transparency. [Online] available at: http://www.ntlfloortrends.com/NFT/Home/Images/nft_0112_EPD_img2.jpg; Accessed: 17th January, 2012.
248. Neuman, W.L. (2006). Social Research Methods, 6th edition, Boston: Pearson/Allyn& Bacon.
249. New, S. J. and Westbrook, R. (2004). Understanding supply chains: concepts, critiques, and futures. London: Oxford University Press. ISBN 9780199259335.
250. Nicol, S. and Thompson, S. (2007). Policy options to reduce consumer waste to zero: comparing product stewardship and Extended Producer Responsibility for refrigerator waste. *Waste Management and Research*, Vol. 25(3), pp. 227-233.
251. Nightingale, D. and Donnette, R. (2002). Household Hazardous Wastes. In Tchobanoglous, G. and Kreith, F. (eds.): The Handbook of Solid Waste Management, second edition, pp. 10.1-10.36. McGraw-Hill, New York.
252. NWPSC. (2010). Northwest Product Stewardship Council – Missions and Objectives. [Online] Available at: http://www.productstewardship.net/about.html. [Accessed on: 2nd March, 2010].
253. OECD. (2001). Extended Producer Responsibility; a Guidance Manual for Governments. OECD Publishing. Paris, France. ISBN: 9789264189867.
254. OECD. (2005). Environment and the OECD Guidelines for Multinational Enterprises: Corporate Tools and Approaches. OECD Publishing, 2005. ISBN 9264009388.

255. Optimat. (2008). *Sustainable Construction Strategy for the UK Concrete Industry (SCSCI)*. Commercial in confidence. 2008.
256. Parrott, L. (2002). Cement, Concrete and Sustainability; A report on the Progress of the UK Cement and Concrete Industry towards Sustainability. British Cement Association.
257. Palmer, K. and Walls, M. (2002). The Product Stewardship Movement Understanding Costs, Effectiveness, and the Role for Policy. Resources for the Future. Washington. [Online] Available at: www.rff.org [Accessed: 10 February, 2010].
258. Parmenter, D. (2007). Key performance indicators: developing, implementing, and using winning KPIs. 2007. John Wiley and Sons, New Jersey. [Online] Available at: http://reader.eblib.com/. [Accessed on 13th July, 2011].
259. PAS 2050. (2011). Specification for the assessment of the life cycle greenhouse gas emissions of goods and services. British Standards Institution. [Online] Available at: http://shop.bsigroup.com/upload/Shop/Download/PAS/PAS2050Guide.pdf. [Accessed on: 8th December, 2012].
260. Philips. (2010). *Corporate website* [Online] available at: http://www.newscenter.philips.com/main/standard/about/news/press/20090225_green_products.wpd[Accessed on: 31st January, 2010].
261. Pitchell, J. (2005). Waste Management Practices: municipal, hazardous and industrial. CRC Press. ISBN-10: 0849335256.
262. PSF. (2009). What is Product Stewardship? Product Stewardship Foundation. [Online] http://www.productstewardship.org.nz/. Available at: [Accessed at: 27th July, 2009].
263. PSF. (2010). What is Product stewardship? [Online] Available at: http://www.productstewardship.org.nz/component/option,com_frontpage/Itemid,1/. Accessed on: 2nd March, 2010.
264. PSI. (2010). What is Product stewardship? [Online] available at: http://www.productstewardship.us/displaycommon.cfm?an=1&subarticlenbr=55; [Accessed on: 14th February, 2010].
265. PSI. (2009). What is Product stewardship? Product Stewardship Institute. [Online] available at: http://www.productstewardship.us/displaycommon.cfm?an=1&subarticlenbr=55; [Accessed at: 27th July, 2009].
266. PSI. (2014). What is Product stewardship? Product Stewardship Institute. [Online] available at: http://www.productstewardship.us/. [Accessed at: 12th March, 2014].
267. PPRC. (2009). *Product Stewardship: Principles of Product Stewardship*. Pacific Northwest Pollution Prevention Resource Centre [Online] Available at:http://www.pprc.org/hubs/subsection.cfm?hub=1009&subsec=11&nav=11&CFID=1334960&CFTOKEN=41804874http://www.pprc.org/hubs/subsection.cfm?hub=1009&subsec=11&nav=11&CFID=1334960&CFTOKEN=41804874[2nd February, 2009].
268. Price Water House Coopers. (2009). A framework for Product stewardship developed for the Environment Protection Heritage Council. [Online] Available at: http://www.epa.vic.gov.au/waste/docs/Product-Stewardship-Framework.pdf. [Accessed on: 20th February, 2010].

269. Rainey, D., L. (2006). Sustainable Business Development - Inventing the Future through Strategy, Innovation, and Leadership. Cambridge University Press. Cambridge. ISBN 0521862787, 9780521862783.
270. Remenyi, D., Williams, B., Money, A. and Swartz, E. (1998). Doing research in business and management: an introduction to process and method. SAGE Publications. ISBN – 0-7619-5950-5, 9780761959502.
271. Roome, N. (1998). Sustainable development and the industrial firm. In: Roome, N. (ed.). (1998). Sustainability strategies for industry: the future of corporate practice. Island Press, Washington, DC.
272. Reason, P. and Bradbury, H. (Eds.). (2001). Handbook of action research: Participative inquiry and practice. London: Sage Publications Ltd.
273. Reason, P. and Bradbury-Huang, H. (Eds.). (2005). Handbook of action research: Concise paperback edition: student edition. London: Sage Publications Ltd.
274. Remenyi, D., Williams, B., Money, A. and Swartz, E. (1998). *Doing research in business and management: an introduction to process and method*. SAGE Publications. ISBN – 0-7619-5950-5, 9780761959502.
275. Responsible Care. (2010). Responsible Care Global Charter. [Online] Available at: http://www.responsiblecare.org/page.asp?p=6341&l=1. [Accessed: 21st February, 2010].
276. Ryding, S. (1998). Environmental management handbook. IOS Press: Amsterderm. ISBN 9051991711, 9789051991710.
277. Sakai, K. (2008). Sustainability in the concrete sector: CO2 reduction scenarios. *Concrete Engineering International*, winter, 2008, p. 8-9.
278. Saunders, M., Lewis, P. and Thornhill, A. (2012). Research Methods for Business Students. ISBN-13: 978-0273750758.
279. Saunders, M., Lewis, P., and Thornhill, A. (2007). Research methods for business students. 4th edition. Pearson Education, Essex. ISBN 0-273-70148-7, 9780273701484.
280. Savage, M., Ogilvie, S., Slezak, J., Artim, E., Lindblom, J. and Delgado, L. (2006). Implementation of Waste Electric and Electronic Equipment Directive in EU 25. Institute for Prospective Technological Studies. Spain. ISBN 92-79-01926-0.
281. Seuring, S. and Müller, M. (2008). From a literature review to a conceptual framework for sustainable supply chain management. *Journal of Cleaner Production*, Vol.16, pp. 1699–1710.
282. SCF. (2010). The Concrete Industry Sustainability Performance Report; 2008 performance data and release of 2012 performance targets. London: Sustainable Concrete Forum.
283. Scheer, D. (2006). Environmental governance and integrated product policy, in Scheer, D. and Rubik, F. (Eds.) .Governance of Integrated Product Policy in Search of Sustainable Production and Consumption. Sheffield: Greenleaf, pp.44–68.
284. Schenck, R. (2009). The Outlook and Opportunity for Type III Environmental Product Declarations in the United States of America. [Online] Available at: Institute for Environmental Research and Education; http://lcacenter.org/pdf/Outlook-for-Type-III-Ecolabels-in-the-USA.pdf. [Accessed on: 11th February, 2012].
285. Sekaran, U. and Bougie, R. (2010). Research Methods for Business; A Skill Building Approach. John and Wiley: Chichester.

286. Shell Chemicals. (2010). Product Stewardship. [Online] available at: http://www.shell.com/home/content/chemicals/responsible_energy/sustainable_development_shell_chemicals/product_stewardship/product_stewardship.htm [Accessed on: 11th February, 2010].
287. Silverman, D. (1997). Qualitative research: theory, method and practice.London : Sage Publications. ISBN: 0803976658.
288. Skaar, C. and Fet, A. M. (2011). Accountability in the Value Chain: From Environmental Product Declaration (EPD) to CSR Product Declaration. Corporate Social Responsibility and Environmental Management. 10.1002/csr.275.
289. Sustainable Concrete. (2010). Precast concrete. [Online] Available at: http://www.sustainableconcrete.org.uk/main.asp?page=62. [Accessed on: 19th August, 2010].
290. Sustainable Concrete. (2014). Sustainable Concrete; the leading material in Sustainable Construction. [Online]. Available at: http://www.sustainableconcrete.org.uk/top_nav/what_is_concrete/precast.aspx. Accessed on: 13th March, 2014.
291. Starke, L. (Ed.). (2003). Breaking new ground: mining, minerals, and sustainable development: the report of the MMSD project. Earthscan Publications Ltd. ISBN-10: 1853839426.
292. Steen, B., Ga¨rling, A., Imrell, A-M, Sanne, K. (2008). Development of interpretation keys for environmental product declarations. *Journal of Cleaner Production*. Vol. 16, pp. 598-604.
293. Stern, N. (2009). A Blueprint for a Safer Planet: How to Manage Climate Change and Create a New Era of Progress and Prosperity. The Bodley Head, London. ISBN-10: 1847920373.
294. Stevens, C. (2014). Sustainability Assessment Methodologies. Available [Online] at; http://www.oecd.org/greengrowth/39925248.pdf. Accessed: 9th March, 2014. OECD Sustainable Development Advisor.
295. Sustainable Concrete. (2009). The Concrete Industry Sustainability Performance Report. [Online] available at: http://sustainableconcrete.org.uk/concrete_sustainable_strategy/concrete_sustainable_report.aspx. [Accessed on: 26th October, 2010].
296. Sustainable Concrete. (2009a). *Sustainable Concrete website* [Online] available at: www.sustainableconcrete.org; [Accessed on: 19th July, 2009].
297. Swamy, R.N. (1998). Designing concrete and concrete structures for sustainable development. V.M. Malhotra (Ed.), ACI SP-178, Vol. 1, pp. 245–255.
298. Tashakkori, A. and Teddlie, Ch. (2003). Major Issues and Controversies in the use of Mixed Methods in Social and Behavioural research", in A. Tashakkori and Ch. Teddlie (eds), Handbook of Mixed Methods in Social and Behavioural Research. Thousand Oaks, CA: SAGE. pp. 3 - 50.
299. The UK Parliament. (2007). Electronic Waste - Parliament. [Online] available at: www.parliament.uk/briefing-papers/POST-PN-291.pdf. [Accessed on: 7th December, 2012].

300. Thomas, A., B. (2003). Research skills for management studies. Routledge; Taylor and Francis Group. London. ISBN 0-415-26899-0, 9780415268998.
301. Thorpe, D., Ryan, N. and Charles, M. (2008). *Environmental sustainability – a driver for innovation in construction SMEs?* In: 3rd International Conference of the CRC for Construction Innovation: Clients Driving Innovation: Benefiting from Innovation, 12-14 March 2008, Gold Coast, Australia.
302. Thorpe, B., Kruszewska, I. and McPherson, A. (2004): Extended producer responsibility: a waste management strategy that cuts waste, creates a cleaner environment and saves taxpayers money. Clean Production Action, 3-28.
303. Toyota (2010). Sustainability Report 2009. [Online] available online at: http://www.toyota.co.jp/en/csr/report/09/download/index.html [Accessed on: 20th February, 2010].
304. UNEP. (2014). Life Cycle Management. [Online]. Available at: http://www.unep.org/resourceefficiency/Business/SustainableandResponsibleBusiness/Life CycleManagement/tabid/78904/Default.aspx. [Accessed on: 12th March, 2014].
305. US EPA (United States Environmental Protection Agency). (2010). What is Product Stewardship? United States Environmental Protection Agency [Online] (Updated 25 September 2009). Available at: http://www.epa.gov/epawaste/partnerships/stewardship/basic.htm#prod. [Accessed on: 24th February, 2010].Wharton School Publishing, Second edition, illustrated. ISBN 0136134394.
306. Vanclay F. (2002). Social impact assessment. In: Munn T, editor. Encyclopedia of global environmentalchange. Vol. 4. Chichester: Wiley, 2002. pp. 387–93.
307. Vastag, G., Corbett, C. and Kirsch D. (2004). Revisiting ISO 14000 diffusion: a new 'look' at the drivers of certifi cation/response. Production and Operations Management 13(3) pp. 260–271.
308. Verghese, K., Lewis, H. and Fitzpatrick. L. (2012). Packaging for Sustainability. Springer. ISBN 0857299875, 9780857299871.
309. Walliman, N. (2011). Your Research Project: Designing and Planning Your Work. London: SAGE Publications. ISBN 1849204624, 9781849204620.
310. Walther, G., Schmid, E. and Spengler, T. S. (2008). Negotiation-based coordination in product recovery networks. *International Journal of Production Economics* 111 (2), 334–350.
311. WBCSD. (2006). Eco-efficiency; Learning module. World Business Council for Sustainable Development. [Online] Available at: http://www.wbcsd.org/web/publications/ee_module.pdf; [Accessed on: 26th March, 2010].
312. WBCSD. (2009). *Sustainability Benefits of Concrete*. World Business Council for Sustainable Development. [Online] available at: http://www.wbcsdcement.org/index.php?option=com_content&task=view&id=67&Itemid=13; [Accessed on: 27th July, 2009].
313. WBCSD. (2012).The Cement Sustainability Initiative; 10 years of progress and moving on into the next decade. Available [Online] at:

http://csiprogress2012.org/templates/rt_voxel/CSI%20Progress%20Report_20120530.pdf. Accessed on: 9th March, 2014.

314. WCED. (1987). Our Common Future. World Commission for Environment and Development. Oxford: Oxford University Press. ISBN-10: 019282080X.
315. Weisbord, G and Weisbrod, B. (1997). Measuring Economic Impacts of Projects and Programs. Economic Development Research Group. [Online]. Availbale at: http://www.edrgroup.com/pdf/econ-impact-primer.pdf. Accessed on: 12th March, 2014.
316. Yin, R. (1994). Case study research: Design and methods. Beverly Hills, CA: Sage Publications. Second Edition.
317. Yin, R.K. (2008). Case Study Research: Design and Methods. Los Angeles: Sage Publications. Fourth Edition.
318. Zackrisson, M., Rochab, C., Christiansenc, K. and Jarnehammar, A. (2008). Stepwise environmental product declarations: ten SME case studies. *Journal of Cleaner Production*. Vol.16 (17), pp. 1872–1886.

APPENDIX A Paper 1

Aliyu, A. A, Glass, J., Clarke, M. A, Elhag, H. K and Price, A.D.F (2009). The need for a product stewardship scheme to improve sustainability in the precast concrete industry. Responsible Leadership. Proceedings of the Corporate Responsibility Research (CRR) Conference 2009, University of Vaasa, Vaasa (Finland), 2009: pp. 1-17. ISBN 978-9-52476-285-4.

The Need for a Product Stewardship Scheme to Improve Sustainability in the UK Precast Concrete Industry

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ABSTRACT

The UK precast concrete industry is widely seen as one of the major players towards the delivery and achievement of the targets of sustainable construction. To improve its sustainability credentials, the precast concrete industry is committed to a more sustainable precast sector through a continuous measurement of performance and improvements across the sector. These have led to the development of a set of sustainability policies base on key issues facing the industry.

Product stewardship schemes help all stakeholders within businesses, companies, organisations and multinational corporations to mitigate the environmental impacts associated with their products throughout the entire life cycle of the product from '*cradle to cradle'* by taking responsibility to address such impacts.

This is a visioning paper for the UK precast concrete industry on how to improve sustainability through product stewardship. The paper introduces the concept of product stewardship, highlights the significance of developing a product stewardship scheme for the industry, explores its benefits and explains why product stewardship should serve as the next step forward for the industry to take voluntarily. The paper will identify useful lessons for the sectors which are intending to develop or deliver a product stewardship scheme.

Keywords: sustainable development; sustainability; sustainable construction; concrete and precast concrete industry; product stewardship

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INTRODUCTION

The sustainability discourse has become an integral part of the UK government policies over the years (DETR, 1999; DEFRA, 1999; DEFRA, 2005; CLG, 2008; BERR, 2008). Government, policy makers, engineers, architects, specifiers, designers, clients and all the stakeholders within the construction industry have recognised the need for a major change in the sustainability of the construction industry (BERR, 2008). Construction product manufacturers and suppliers have been identified as crucial components of the supply chain towards the delivery of a more sustainable future (CPA, 2007). The increase in the demand for more sustainable construction products will help towards the achievement of sustainable construction in the UK construction industry.

The UK precast concrete Industry's sustainability programme has a national importance to the Government's sustainability agenda. Within this, the precast concrete industry aims to achieve a more sustainable built environment through the use and reuse of precast concrete products, measurement, improvements and promotion of; the health and safety performance of the sector, pollution/emission, waste and embodied energy reduction, efficient minimisation of resource use (materials and water), productivity, environmental impact reduction, supply chain management, stakeholder engagement, auditing of key performance indicators and the respect for people and their communities.

This paper provides an introduction to the UK precast concrete industry, its sustainability programme *'More from less',* the product stewardship discourse and the need for a fully-fledged product stewardship scheme for the industry to improve its sustainability credentials. The paper aims to show the benefits associated with similar schemes that have been implemented by other industries in Europe and internationally.

PRECAST CONCRETE PRODUCTS AND THE UK INDUSTRY'S PROGRESS ON SUSTAINABILITY

Precast concrete products are made in factories, transported to sites or cast on construction sites but remote from their last position or location (Clarke and Glass, 2008). In terms of products, precast concrete products range from:

> "*small hydraulically pressed items mass produced in highly automated factories, such as concrete bricks, paving and roof tiles, to larger mass produced items such as pipes, piles and floor beams, and individual structural units manufactured to specific engineering and architectural requirements*"(Holton, 2008).

Precast products are manufactured and produced to the highest quality standards; the process of manufacture involves a combination of both skilled labour and automated processes. Precast concrete elements are well known globally as established methods of construction with flexibility and variety (Concrete Centre and British Precast, 2007). Precast concrete products help to shape the built environment through the provision of building envelopes, supporting structures and services for public and private housing, industrial and institutional buildings, retail and commercial buildings. The UK precast concrete industry's roots can be traced at the end of the 19th century when entrepreneurial engineers and builders realised the importance of high quality and the economic advantages offered by casting concrete with the use of machines (Clarke, 2003). Today in the UK, precast concrete production stands at over 36 million tonnes of products annually, worth in excess of £2.3 billion (Holton, 2008). There are over 800 precast concrete companies in the UK (Sustainable Concrete, 2009) with around 23,000 employees (BIBM, 2008) and more in the upstream and downstream sector of the UK economy. This forms part of the wider construction industry which employs 7% of the UK population (BCA, 2006) and accounts for 8% of Gross Domestic Product (GDP) (BERR, 2008). The precast concrete industry in the UK is an important sector of the UK construction products industry (Holton *et al.*, 2008) and by extension the construction industry, which includes building, civil engineering, construction materials and products, and associated services (Holton *et.al*, 2008). According to the Construction Products Association (CPA), the largest amongst the four different, but related, activities is the construction materials and products, which has a total annual turnover of more than £40 billion (CPA, 2009).

The British Precast Concrete Federation (BPCF), the umbrella body for the UK precast concrete industry, devised a sustainability programme "*More from Less*" in 2004 to address the sustainability issues and activities of the industry. Still ongoing, the programme was purposefully aimed at measuring, improving, promoting and boosting the environmental, social and economic credentials of precast concrete products in the UK. As a result, a sector sustainability strategy was developed and implemented to move the precast concrete industry forward (Holton et. al., 2009) and help the precast concrete industry better position its future profitability and competiveness (Holton, 2006). That said, according to (Wolschner et al., 2008), the precast concrete industry depends more broadly on its suppliers' environmental performances, e.g. cement production, carbon emissions, how suppliers of aggregates deal with landscape issues or the environmental performance of concrete additives. In the manufacturing process, precast concrete does consume energy, but its more energy intensive raw materials (i.e. cement) contribute the larger CO_2 emissions and impacts. The entire life-cycle of precast concrete products produce a range of impacts from all the various production processes to end of-life, i.e. from sourcing and extraction of raw materials to the final use and disposal stage. These are areas of particular concern and will be addressed later in this paper, after a more detailed examination of progress within the industry.

As the precast concrete trade association, BPCF is showing commitment to achieve a more sustainable precast concrete sector. According to the first sustainability report for the precast concrete industry (BPCF, 2005), the precast concrete industry recorded major achievements on sustainability from 1999 with the formation of Environment, Health and Safety committees to provide a pan-sector approach in dealing with important sustainability issues facing the industry. By 2001, the Concrete Targets Award scheme was launched. This scheme was launched in a rapid response to the Government's 'Revitalising Health and Safety' initiative (HSE, 2009) and was followed by The Concrete Targets (CT 2010) scheme in 2006, to improve the health and safety performance of the industry by 50% reduction of RIDDOR (Reporting of Injuries, Diseases and Dangerous Occurrences Regulations) reportable accidents and lost time injury by 2010.

In 2002, the best practice awards were initiated to promote excellence and recognise members that had made progress on innovation, health, safety and the environment. In the same year, BPCF joined the DEFRA and DTI 'Pioneers Group' to demonstrate its intention to develop a sector sustainability strategy for the precast concrete industry. As a result, in 2003, BPCF's council approved sponsorship of an Engineering Doctorate (EngD) project in the Department of Civil and Building Engineering, Loughborough University to develop a sector sustainability strategy for the precast concrete industry which started in 2004. In 2005, a joint approach to sustainability from the cement and concrete industry was facilitated by the Concrete Sector Sustainability Working Group. Finally, a Sustainability programme was approved by the BPCF Council in 2007 to boost performance across the whole precast concrete industry on sustainability to include:

- Key Performance Indicators
- Sustainability Charter
- Certification Scheme
- Best Practice Forum
- Objective, Indicators and Targets for improvement

The sustainability charter was purposely launched to engender commitment of all BPCF member companies to a designed set of sustainability guided principles (BPCF and Construction News, 2008). The year 2008 saw an industry consultation and charter audits to encourage BPCF's member to go beyond legislation and to take deliberate actions in making their products and operations more sustainable. As can be seen, there has been a clear demonstration of commitment and progress by BPCF and its member companies in making the precast concrete industry more sustainable, with a framework for management, measurement and monitoring now in place. However, further steps need to be taken to improve the level of 'responsibility' being demonstrated throughout the life-cycle of precast concrete products. To continue with the '*More from Less*' sustainability programme of the precast concrete industry, a four year collaborative research - Engineering Doctorate (EngD) began in October, 2008 to further improve the sustainability of the precast concrete industry. In this case, the use of product stewardship was proposed as a possible way forward and is discussed next.

ABOUT PRODUCT STEWARDSHIP

To understand the term 'Product Stewardship' (PS), an extensive literature review was carried out from which it was clear that there was no single agreed definition, which is similar to the discrepancies found when attempting to characterise other terms in the field of environmental policy (Merlot, 1998, Lewis, 2004,) such as sustainability or sustainable development. Various authors, governmental organisations and Non-governmental organisations (NGO's) however agree that PS involves a 'shared responsibility' (Starke, 2003 Lewis, 2004; McKerlie, *et.al*, 2006a; PSI, 2009; PSF, 2009; USEPA, 2009; PPRC, 2009a). This section will look at various definitions of PS to gain a broad understanding of the concept as used in the fields of environmental policy and various industries.

Product stewardship encourages businesses to become more responsible through proper ethical management and helping business reduce cost and liabilities (Johnen*et al.*, 2000). The concept of PS was introduced in 1972 by the then President of Dow Chemical, Ben Branch to alleviate risks in the use of chemicals (Rainey, 2006) and the company has now become one of the leaders in this area, defining PS as: *"the process and activities of making health, safety and environmental protection an integral part of designing, manufacturing, marketing, distributing, using, recycling and disposing of our products*" (Dow, 2008). However, the most widely used definition emanates from the United States Environmental Protection Agency (US EPA), which defines PS as:

> "*A product-centred approach to environmental protection. It calls on those in the product lifecycle—manufacturers, retailers, users, and disposers—to share responsibility for reducing the environmental impacts of products*" (US EPA, 2009).

Indeed, The Product Stewardship Foundation (PSF, 2009) now defines product stewardship as a 'cradle to cradle' methodology that helps reduce the environmental impact of manufactured products.", whereas Carlton and Thompson (2009) see it as the "*responsible use and management of products during the* *complete product lifecycle from discovery through manufacture and use to disposal*". Taking the business management perspective a little further, Kodak attempt to describe PS as an integrated business process for:

> "*…identifying, managing and minimizing the health, safety and environmental risks throughout all stages of a product's life in the best interest of society and our key stakeholders; customers, employees and shareholders*" (Kodak, 2009).

However, Nicol and Thompson (cited in Thorpe et al. 2004), argue that "*product stewardship programmes are a 'step in the wrong direction because they will not lead to better and safer product design nor will they lead to the phase out of hazardous chemicals in the product"*. This view however, appears to have little support from the various industries that have implemented PS schemes and principles in their operations and businesses.

Product stewardship and Extended Producer Responsibility (EPR) vary in actual practice; however these terms are often used interchangeably (Worrell and Appleby 2000). According to Holton et al. (2009) product stewardship is often referred to as EPR, for example the US EPA suggests PS is also known as extended producer responsibility (EPA, 2008). However, McKerlie*et al.* (2006) and Nicol and Thompson (2007) observe that there is confusion about the use of these terms noting that there are important differences between product and producer responsibility policies in their approaches to mitigate environmental impacts of products. That said, Europe, Latin America, Canada, Japan have enacted EPR policies (Lease, 2000, Veleva, 2009). In Europe, three directives by the European Union (EU) have been legislated and are being implemented, including:

I. **Waste Directive; theWaste Electrical and Electronic Equipment (WEEE) directive and the associated Restriction of Hazardous Substances (RoHS);** WEEE directive took effect from January, 2007 (Environment Agency, 2009b). The objective of the scheme is to increase the level of recycling and/or re-use of electrical products (European Union, 2009). The directive focuses on the environmental performance of businesses of electrical and electronic equipment. It stipulates that manufacturers, suppliers and users to recycle and recover electrical and electronic equipment. All consumers are required to return all used e-waste without a charge.

II. **End-of-Life Vehicles (ELVs) Directive**; addresses the handling and disposal of vehicles at the end of their life. The directive instructed each EU member state to implement a National Regulations on ELVs. Published by the European Union (EU), the directive "*aims at making vehicle dismantling and recycling more environmentally friendly, sets clear quantified targets for reuse, recycling and recovery of vehicles and their components and pushes producers to manufacture new vehicles also with a view to their recyclability*" (European Commission, 2009).

III. **Packing and Packaging;** Directive 94/62/EC was adopted by the European parliament and the Council of Ministers in 1992, which aims to prevent and reduce impacts arising from packaging and packaging waste. It was also aimed at harmonising national measures to reduce such impacts

(European Commission, 2009). Lewis (2004) note that for more than 20 years, the packaging industry has been under pressure to reduce its environmental impacts.

Product Stewardship principles have been developed (PPRC, 2009) to help in the development of voluntary agreements between councils, environmental groups, organisations and trade associations on how to reduce health and environmental impacts of products. According to the Product Stewardship Institute (PSI, 2009), the principles of product stewardship are:

Responsibility: reducing the environmental impact of products should be shared amongst the industry (designers, manufactures and retailers of products including product components).

Internalise costs: the total product cost should include the whole life cycle of the product from the resources use to the final disposal which should be minimised.

Incentives for cleaner products and sustainable management practices: implementing and promoting policies that create incentives from designing to the manufacture of cleaner products.

Flexible management strategies: effectively looking at ways to address products environmental impacts.

Roles and relationships: the collaboration of all parties involved from industry, government and consumers will help in the promoting the practices of product stewardship throughout the product's lifecycle.

These principles were designed to promote and develop appropriate practices, creating an efficient and effective way of mitigating environmental and social impacts in a products' life cycle through shared and multi-stakeholder responsibility. But it is not easy to interpret and hence operationalise these principles; indeed, Roy and Whelan (1992) are of the view that the main components of product stewardship are much less easy to define, but they suggest that these could include:

- Equipment design and material selection;
- Environmental impact of manufacturing processes;
- Logistics of collection at the end-of-life;
- Disassembly of equipment, and reclamation of scrap;
- Recycling;
- Economics of recycling;
- Safe disposal of any hazardous residual components; and,
- Communication with external organisations – consumer groups, legislature, and industry at large.

The above list places emphasis across the entire product life-cycle from design and material selection to end-of-life stages, in addition to communication with relevant stakeholders. The application of this approach to the precast concrete industry is discussed later in the paper, but the next section considers a few selected case studies of industries that have applied PS schemes.

CASE STUDIES OF PRODUCT STEWARDSHIP

In North America and some parts of Europe, several major companies within key sectors of the economy have implemented PS schemes and several stewardship councils that represent key sectors of the economy have also implemented these schemes, including the Marine Stewardship Council and the Forestry Stewardship Council. Various national governments and multinational corporations have implemented Product Stewardship schemes to manage the environmental, health and safety issues in the life-cycle of their products, from manufacture to final use stages (cradle to cradle). These have included the agricultural, petrochemical, steel, chemical, IT, automobile and other industries – two examples are shown below.

Chemical industry: here, product stewardship reduces the risks associated with process and chemical hazards in a company's supply chain (Snir, 2001, p.190). The Chemical Industry, under the International Council of Chemical Associations (ICCA) adopted the Strategic Approach to International Management (SAICM) in 2006 (ICCA, 2009), which is an international framework for global chemicals management (ICCA, 2007). The ICCA has also introduced the Global Product Strategy (GPS) which includes product stewardship activities and also a Responsible care® initiative. These initiatives serve as the industry's mechanisms for managing environmental, health and safety aspects of a chemical throughout its life cycle.

Agrochemical industry: presently, a handful of major companies are taking leading stewardship roles in the agrochemical industry through advice to users, distributors, farmers and contractor applicators (Carlton and Thompson, 2009b). This advice will significantly improve the safety of growers and farmers, safe storage and disposal methods, reduce environmental impacts, help stakeholders within the sector to understand best practices in handling products and promote further stewardship management measures and programmes.

A comparative analysis of these industries and different product stewardship councils' models will be considered in a future paper to understand and synthesize their approaches, implementation methods and criteria.

Having a closer look at some of the benefits of PS will show that PS helps to induce a rich variety of product innovations aimed at reducing waste management cost by waste prevention, re-use, recycling and toxin reduction (Michaelis, 1995), reduce cost and liabilities (Johnen *et al.*, 2000), serve as a marketing tool that helps create business value, competitive advantage and strengthens relationships with stakeholders (Shell, 2008). That said, it is possible to summarise the benefits associated with PS; these are numerous and generic, but the ability to capitalise on these will depend on the industry within which PS is applied:

- Building social responsibility through increased awareness and collaborative responses to environmental issues across stakeholders

- Reducing the number, scale and costs of landfills and waste treatment facilities and their accompanying environmental impacts
- Decreasing or eliminating potentially hazardous components of products
- Promoting cleaner production and products
- Promoting more efficient use of natural resources and materials
- Closing of material loops to promote sustainable development
- Encouraging more efficient and competitive manufacturing, and
- Promoting more integrated environmental management by emphasising the product's life cycle.

In addition, businesses can gain market advantage through environmental leadership, achieve a greater adaptability within the Government policy/legislative frameworks, together with some direct returns, such as energy and resource savings, reduced cost of pollution control measures and better product design (Department of Environment and Conservation, and Waste Management Board, Australia, 2006). Arch Chemicals (2009) a leading company in the chemical industry outlines the following as long term but less immediate benefits of PS:

- Help to increase productivity; due to evidence of health and safety measures taken by companies to safeguard workers and their working environments.
- Enhance credibility of products and businesses investment in health, safety and environmental protection early in the product life cycle may pre-empt far greater expenditure for remediation or other corrective measures.
- Provides a competitive advantages; PS anticipates and addresses increasing demand for safer, more environmentally sound products - demands that translate into sales. PS also involves strengthening relationships with customers, thus improving the quality and timeliness of market information.
- Reduction of liabilities; Because of its focus on customer education and involvement, an effective PS initiative should help to reduce future liability claims. Similarly, the active participation of contract manufacturers, distributors, suppliers and employees should help ensure the proper handling of raw materials and finished products, thus mitigating potential liabilities.

The final section considers the possible introduction of a PS scheme within the UK precast concrete industry.

DISCUSSION: WHAT COULD PRODUCT STEWARDSHIP OFFER THE PRECAST CONCRETE INDUSTRY?

The precast industry designs, produces and consumes precast concrete products for use in the built environment. As a major player within the construction industry, the precast concrete sector needs to face these challenges to manufacture products that suit these requirements in relation to government, client and other stakeholder requirements for more sustainable construction. For example, UK and EU legislation, product standards, government strategy and market mechanisms are all putting pressure on the industry to change (CPA, 2007). According to DEFRA, the Government needs a more sustainable approach on resources use and a reduction of waste going to landfill (DEFRA, 2009). With the construction industry producing around 90 million tonnes of construction, demolition and excavation (CD&E) inert waste, UK government intends to halve waste to landfill by 2012 (BERR, 2008). This also corresponds to the target set by the UK Concrete Industry's Sustainable Construction Strategy for the UK Concrete Industry (Optimat, 2008).

Mehta (2001) suggests that the concrete industry can reduce its environmental impact through resource productivity by energy and material conservation in making concrete and by improved concrete durability of products. In addition, Sinclair and Quinn (2006) believe that some of the major reasons why there is an increase in wastes are as a result of societal over consumption, ineffective production process and poor product design. So, there is scope to improve the product stewardship of precast concrete products at various stages. Figure 4 represents a typical sequence of a precast concrete product through its entire life-cycle. By sharing responsibility by all stakeholders, this can guarantee a reduced environmental impact of products since there are people to be held responsible for these impacts. It means all stakeholders associated with the sourcing, production, manufacture, transportation, use, disposal, retail, reuse, recycling and disposal of precast concrete products take responsibility to abate or mitigate the environmental and social impacts of the product.

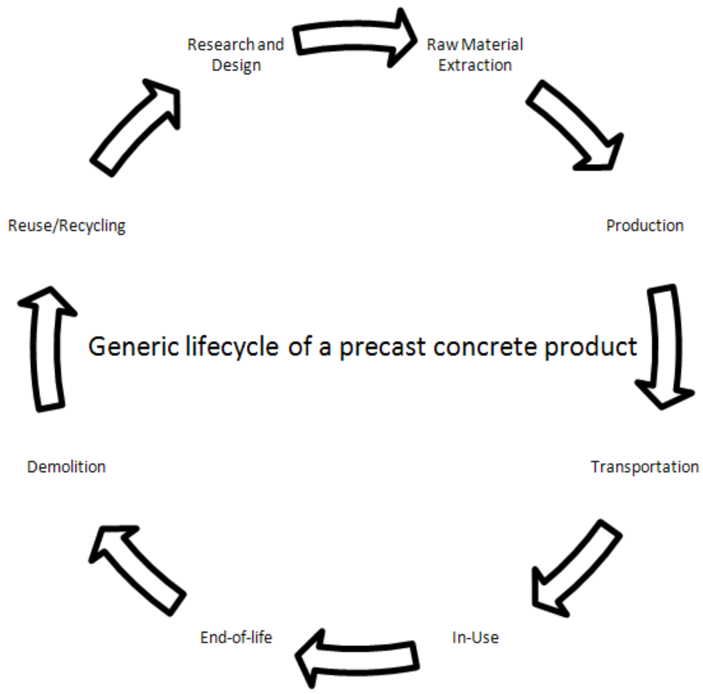

Figure 4: A generic Life-cycle of a precast concrete product

The established *"More from Less"* sustainability programme could use a sustained product stewardship approach, by looking at the entire life cycle of precast concrete products from cradle to cradle, i.e. by efficient and effective use of constituent ingredients in the whole precast production processes from extraction and sourcing of raw materials, mix design, production, consumption and end-of-life usage. This could help the industry to contribute meaningfully to the UK government's policies, plus clients' and stakeholders' demands for more sustainable construction. For example, it could help mitigate impacts arising from transport, energy, resource use (materials, water and waste) among others. The UK concrete industry's guidance document on responsible sourcing of construction products provides an indication of its willingness to adopt this approach, espousing;

> "*...a holistic approach to managing the social, environmental and economic impacts of a product from the sources of its raw materials, through its manufacture and delivery, and, ideally, through its use, re-use and recycling, until its final disposal as waste with no further value*" (CISFC, 2008).

Furthermore the Building Research Establishment (BRE) in collaboration with the UK precast concrete industry and others have developed a framework standard for the Responsible sourcing of construction products (BRE BES6001: 2009 Issue 2). According to BRE Global (2009), "*Responsible sourcing of materials (RSM) is demonstrated through an ethos of supply chain management and **product stewardship** and encompasses social, economic and environmental dimensions*". BES 6001 provides a route to BREEAM family certification scheme through obtaining credits. It has set a standard with some compulsory elements that each organisation must meet in addition to a higher compliance level that leads to higher performance being awarded. Currently, the British Standards Institution (BSI, 2009) is also developing BS8902, a draft standard on Responsible sourcing sector certification schemes. Notwithstanding these developments, a certified and fully-fledged Product Stewardship scheme for the UK precast concrete industry could help in the overall improvement of the environmental, social and economic performance of all precast concrete products not just from responsible sourcing of precast concrete products but throughout the entire products lifecycle, i.e. from cradle to cradle.

CONCLUSION

The UK precast concrete sectors' sustainability credentials could be improved through a voluntary, but thorough and in-depth improvement of environmental, social and economic issues affecting the industry. These key issues can be bridged by a dedicated Product Stewardship scheme for the UK precast concrete industry which will be all encompassing in the reduction of environmental and social impacts at all the key stages involved in a precast concrete product's life cycle. A Product stewardship scheme will provide a framework to help the UK precast concrete industry identify and mitigate the environmental and social impacts of its products throughout their life-cycle. The scheme should help in enhancing the environmental credentials and performance of precast products through impact reduction. It will pave the way towards a successful delivery of sustainable construction and, by extension, help create a more sustainable built-environment in the UK and globally. The benefits of a precast PS scheme may not only be continued and sustained growth, sustainable environments and social wellbeing, but it could also produce an efficient and effective index to measure and improve the entire performance of the concrete and precast concrete sector globally.

REFERENCES

Arch Chemical. 2009. *Product stewardship - Benefits*. [Online] Available at: http://www.archchemicals.com/Fed/Urethane/About/benefits.htm. [Accessed on: 15th July, 2009].

BERR. 2008. *Strategy for Sustainable Construction*. Department for Business, Enterprise and Regulatory Reform (BERR) HM Government.

BIBM. 2008. *British Precast Concrete Federation*. European Precast Book 2008, Galazzano: Bureau International du Béton Manufacturé.

BCA. 2006. *Performance: A corporate responsibility report from the UK cements industry,* British Cement Association, 2006. Surrey.

British Precast and Construction News. 2008. *Building Excellence in Precast; Sustainability, Health and Safety, Innovation and Projects*, London: BPCF.

BRE Global. 2009. *BRE Environmental and Sustainability Standard; Framework Standard for the Responsible Sourcing of Construction Products.* Issue 2.0.pp.1-28. British Research Establishment.

BSI. 2009. *BS8902 - a draft standard on Responsible sourcing sector certification schemes for the construction products-specification*. British Standards Institution [Online] Available at:http://www.bsi-global.com/en/Shop/Publication-Detail/?pid=000000000030191222http://www.bsi-global.com/en/Shop/Publication-Detail/?pid=000000000030191222. [Accessed on 9th July, 2009].

Carlton, R. and Thompson, H. 2009. *Product Stewardship - Is there a role for better collaboration?* Outlooks on Pest Management, Volume 20, Number 3, June 2009, pp. 126-127(2).Research Information. ISSN 1743-1026, Online ISSN: 1743-1034.

Clarke, M. 2003. *British Precast - a Profile.* Concrete for the Construction Industry; Precast focus Vol. 37, Part 11, p. 6-7. The Concrete Society: London. ISSN 0010-5317.

Clarke, M. A and Glass, J. 2008. *Forget the Concrete: It's the added Value that counts. Proceedings of the International Conference on Concrete: Construction's Sustainable Options*, 8-10 July, 2008. University of Dundee: Dundee, pp.1-8.

Concrete Centre and British Precast. 2007. *Precast Concrete in Buildings; a guide to design and construction*. Concrete Centre and British Precast 2007.

CISFC. 2008. *Concrete Industry Guidance Document to support BRE Global BES 6001. Issue 1.* Concrete Industry Sustainable Construction Forum [Online] Available at: www.sustainableconcrete.org.uk. [Accessed on: 8th July, 2009].

CLG. 2008. *Sustainable Development Action Plan 2007-2008*. Department for Communities and Local Government, London.

CPA. 2007. *Delivering sustainability; the contribution of construction products.* Construction Product Association. London.

CPA. 2009. *The Construction Products Industry*. Construction Product Association website. [Online] Available at: http://www.constprod.org.org.uk. [Accessed on: 21st June, 2009].

CT 2010. 2009. *Concrete Targets 2010 Health and Safety Scheme*. [Online] Available at: http://www.britishprecast.org/documents/SustainabilityMatters06.pdf. [Accessed on: 10th January, 2009].

DEFRA. 1999. *Securing the future; the UK Governments sustainable development strategy*. Department of Environment, Food and Rural Affairs, London.

DEFRA. 2005. *One future – different paths; the UK's shared framework for sustainable development.* Department of Environment, Food and Rural Affairs, London.

DETR. 1999. *A Better Quality of Life: a strategy for sustainable development in the UK*. Department of the Environment, Transport and the Regions, London.

Dow Chemical. 2009. *Our Company*, [Online] Available at: http://www.dow.com/about/ [Accessed on: 2nd February, 2009].

Eli M. Snir. 2001. *Liability as a catalyst for product stewardship*. Production and Operations Management. Vol. 10, Issue 2, pp. 190-206.

Environment Agency. 2009. *Waste electrical and electronic equipment (WEEE)*, [Online] Available at: http://www.environment-agency.gov.uk/business/topics/waste/32084.aspx.[Accessed on: 29th January, 2009].

Environment Agency.2009b. *End of Life Vehicles Directive*. [Online] Available at: http://www.environment-agency.gov.uk/business/regulation/31887.aspx. [Accessed on: 8th July, 2009].

European Commission. 2009. *Waste; End of Life Vehicles*. [Online] Available at: http://ec.europa.eu/environment/waste/elv_index.htm. [Accessed on: 8th July, 2009].
European Commission. 2009. *Packaging and Packaging Waste*, [Online] Available at: http://ec.europa.eu/environment/waste/packaging_index.htm. [Accessed on: 9th July, 2009].

Holton, I, Glass, J, and Clarke, M.A. 2009.*More from Less – Outcomes from the UK precast concrete industry sustainability programme*. Concrete: 21st Century Superhero. *Fib symposium*, London, June, 2009.

Holton, I. 2005. *Sustainability Matters; 1st Annual progress report from the Precast Industry*, BPCF, Leicester: British Precast, December, 2005, p.1-6.

Holton, I. 2006. *Sustainability Matters; 2nd Annual progress report from the Precast Industry*, BPCF, Leicester: British Precast, December, 2006, p.1-8.

Holton, I. 2008. *Sustainability Matters; 3rd Annual progress report from the Precast Industry*, BPCF, Leicester: British Precast, February, 2008, p. 1-12.

Holton, I. 2009. *Sustainability Matters; 4th Annual progress report from the Precast Industry*, BPCF, Leicester: British Precast, March, 2009, p. 1-12.

Holton, I, Glass, J, and Price, A. 2008.*Developing a Successful Sector Sustainability Strategy: Six Lessons from the UK Construction Products Industry*. Corporate Social Responsibility and Environmental Management, Vol.15, pp. 29-42.

HSE. 2009. *Health and Safety Commission (HSC) Case study; Revitalising Health and Safety*. [Online] Available at: http://www.hse.gov.uk/revitalising/casestudyconcrete.pdf. [Accessed 13th June, 2009].

ICCA. 2007. *Product Stewardship Guidelines*. International Council of Chemical Associations [Online]. Available at: www.icca-chem.org/Home/ICCA-publications/Publications-Search-Results/?topic=Product+Stewardship. [Accessed on: 8th July, 2009].
ICCA. 2006. *ICCA Commits to Improve Chemicals Management; Launches Two New Initiatives to Support SAICM.* International Council of Chemical Associations[Online] Available at: http://www.icca-

at-dubai.org/dbfiles/1853%20ICCA%20RC%20GPS%20Dubai%2005%2002%2006.pdf. [Accessed on: 8th July, 2009].

Johnen, B, Foster, L and Thomas, M. 2000. *Stewardship in the Agrochemical Industry*. Zeneca Agrochemicals. [Online] Available at: http://www.rsc.org/delivery/_ArticleLinking/DisplayArticleForFree.cfm?doi=b006246o&JournalCode=PO. [Accessed on: 13th July, 2009].

Lease, K. 2000.*Facts to Act; Product Stewardship in British Columbia*, Institute for Local Self–Reliance.[Online]. Issue 39, p. 1-8. Available at: http://www.productstewardship.us/associations/6596/files/PSBC.pdf. [Accessed on: 27th January, 2009].

Lewis. H. 2004. *Defining product stewardship and sustainability in the Australian packaging industry. Environmental Science and Policy. [Online]* Vol.8, Issue 1 pp. 45-55.[Accessed on: 8th July, 2009].

Mehta, K. P. 2001. *Reducing the Environmental Impact of Concrete; Concrete can be durable and environmentally friendly*. Concrete International. Autumn edition. USA.

McKerlie, K, Knight., N and Thorpe., B. 2006. *Advancing Extended Producer Responsibility in Canada*. Journal of Cleaner Production, Vol. 14. 2006. pp. 616 - 628.

Merlot, R. 1998.*Product Stewardship: the case of digital equipment corporation*. In: M. M. Kostecki (editor). *The Durable Use of Consumer Products; new options for business and consumption*. Illustrated edition, pp.97-104.Springer, 1998.ISBN 0792381459, 9780792381457.

Michaelis, P. 1995. *Product Stewardship, Waste Minimization and Economic Efficiency: Lessons from Germany*. Journal of Environmental Planning and Management, Vol. 38, No. 2, 1995. pp. 231 - 243.

Nicol, S. and Thompson, S. 2007.*Policy options to reduce consumer waste to zero: comparing product stewardship and Extended Producer Responsibility for refrigerator waste. Waste Management and Research*, Vol. 25. No. 3, pp. 227-233.

Nicol and Thompson. 2001.cited in Thorpe, B., Kruszewska, I. and McPherson, A. 2004. *Extended producer responsibility: a waste management strategy that cuts waste, creates a cleaner environment and saves taxpayers money. Clean Production Action.* [Online] p. 3–28. Available at: http://www.cleanproduction.org/epr/tool_kit.htm. [Accessed on: 10th January, 2009].

Optimat. 2008. *Sustainable Construction Strategy for the UK Concrete Industry (SCSCI)*. Commercial in confidence. 2008.

APPENDIX B Paper 2

Reference: Aliyu, A. A., Glass, J., Price, A.D.F and Elhag, H. K. (2012). "*Assessing the potentials of product stewardship for the precast concrete industry"*. Concrete in the Low Carbon Era Conference, University of Dundee 2012: Dundee (Scotland) 2012: pp.374 - 386. ISBN 978-0-9573263-0-9.

ASSESSING THE POTENTIAL OF PRODUCT STEWARDSHIP FOR THE UK PRECAST CONCRETE INDUSTRY

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ABSTRACT

Sustainability and climate change have now become business imperatives to governments, businesses and all stakeholders in different sectors and industries. In the UK, the UK Government has shown strong commitment for sustainable construction over the years. The strategy for sustainable construction in 2008 has clearly underlined and shown areas that need the construction industry's attention which include: Climate change mitigation, Climate change adaptation, Materials, Water, Waste, Biodiversity and Materials. As part of a four year engineering doctorate research programme aimed at improving the sustainability of the UK precast concrete industry through Product Stewardship (PS), this paper explores the possibility of implementing the principles of PS in the UK precast concrete industry.

Product stewardship (PS) helps all stakeholders within the lifecycle of a product to share, own or take (full or part) responsibility for reducing, mitigating or abating the environmental impacts of the product throughout its lifecycle. Governments, countries, corporate organisations and industries globally that manufacture different products, have recognised the importance of reducing the negative environmental and social impacts of products, goods and services through the development and implementation of PS programmes and initiatives.

This research paper consists of an analysis of 2006 to 2010 key performance indicators of the UK precast concrete industry and findings from 12 industry interviews. Manufacturers' understanding of PS, its potential areas of operation and implementation were investigated. Potential gaps in the sustainability management of these companies were identified and possible PS options were assessed. The paper concludes with a discussion of whether there is any synergy between PS and existing industry initiatives on sustainable construction.

Keywords:
Product stewardship, Sustainable construction, Corporate Sustainability, Environmental impacts; research, Low carbon.

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INTRODUCTION

Precast concrete products are widely used in the UK construction industry and their advantages are numerous. The question of how to manufacture and produce precast concrete products with minimal or zero environmental impacts in modern day production and consumption cycles has been a major source of concern to both manufacturers, consumers and other stakeholders in recent years.

The UK precast concrete industry devised a sustainability programme ('*More from less'*) in 2004, to measure and improve the environmental, social and economic credentials of precast concrete products. A sector sustainability strategy was developed and fully implemented [1] by 2008. Following the success of the '*More from less'* programme, British Precast Concrete Federation (BPCF) also known as British Precast in collaboration with Loughborough University decided to explore and understand the business and performance benefits of the concept of product stewardship (PS) in the precast concrete industry. PS is therefore being assessed for possible implementation through life-cycle thinking and shared responsibility by identifying and mitigating key environmental and social impacts of the industry [2]. Impacts within a product‗s life-cycle at different key stages result from: mineral or material extraction, design and development, production, transportation, use and end-of-life (cradle to cradle). A range of initiatives have been implemented through voluntary and regulatory frameworks to reduce these impacts in different industries (for example, the precast industry has been monitoring and measuring performance through the collation of Key Performance Indicators, or KPIs, since 2006).

Overarching this, the UK government, through different policy documents, has demonstrated the need for a more sustainable construction industry. The 2008 'Strategy for Sustainable Construction' (SSC) highlighted several areas that need the construction industry‗s attention these include; Climate change mitigation and adaptation, Materials, Water, Waste, Biodiversity and Materials [3]. The strategy further provides clarity regarding the UK government‗s current and future policy frameworks and ways of achieving its aims. Climate change mitigation was recognised as one of the most important areas for addressing sustainable development and the UK government has revised the targets set to an 80% cut in greenhouse gas emissions by 2050 (based on 1990 baseline year) and 34% by 2020. Initially, government made a commitment of 60% cut in the Climate Change Act. Presently, all new homes and schools should be zero carbon or carbon neutral by the year 2016, public sector non-domestic buildings should be zero carbon or carbon neutral by 2018 and other non-domestic buildings should also be zero carbon or carbon neutral by 2019. All these targets form part of the UK‗s Low Carbon Transition Plan [3]. The government has also set a target of 50% reduction of construction, demolition and excavation waste sent to landfill by 2012 (based on 2008 levels). There is also regulatory pressure from the EU in the form of Construction Product Regulation (CPR) which comes into force on the 1st July, 2013 making it mandatory for construction products which fall under the CPR scope to be CE marked by declaring a product's performance before they are being sold in the EU [4].

Other areas include developing a robust adaptation approach to climate change, conserving and enhancing biodiversity at all stages of development, using materials with least environmental and social impacts in construction and the reduction of per capita consumption of water in homes. The UK government through the principles of the SSC believes the construction industry can achieve sustainable construction. Within the UK concrete industry, targets have been set by the industry to be identified as a leader in sustainable construction by 2012. The priorities for the industry are the same as those of the SSC and are powerful drivers for any sustainability initiative within the precast concrete industry.

This research paper explores the potential of PS for the UK precast concrete industry. Some of the key concepts enshrined in PS are already evident within the industry, including: responsible sourcing, waste and water minimisation and environmental management. However, the key challenge is to evolve a holistic and robust PS initiative that will link all sustainability management efforts within one PS framework. This paper outlines key performance indicator data, to establish the status of the industry and reflects on industry's current understanding of PS. It concludes with some specific recommendations for the development of a PS framework for the UK precast industry.

PRODUCT STEWARDSHIP

PS, as a subset of sustainability and sustainable development in the field of environmental management [5], requires all stakeholders to take some form of responsibility for example physical and/or financial responsibility for mitigating the life cycle environmental and social impacts throughout the supply chain [6], and from 'cradle to cradle', although it lacks a single unified definition. PS encourages business to become more responsible through proper ethical management and reducing costs and liabilities [7]. PS helps stakeholders within businesses, companies, organisations and multinational corporations to mitigate the environmental impacts associated with products throughout their entire life cycle. A conceptual understanding for the key components in PS is shown in Figure 1. A more detailed process tree is also shown in Figure 2.

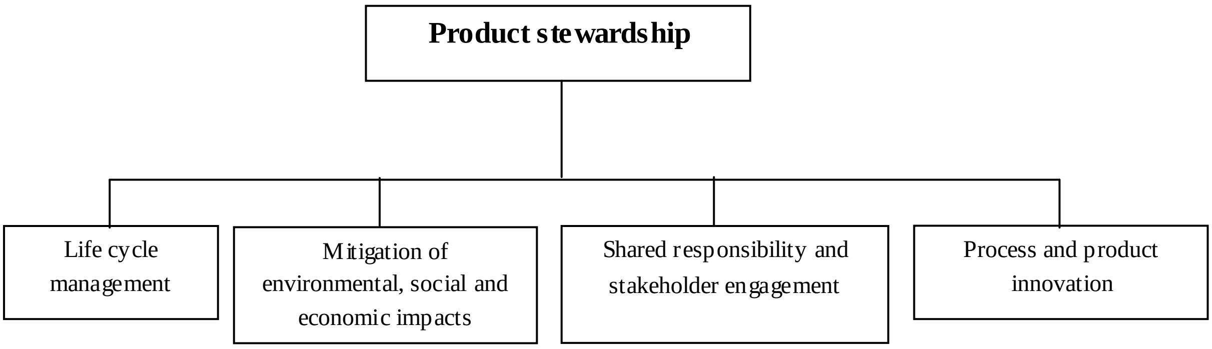

Figure 1 Key components of product stewardship

Brady et.al [8] described PS as a key tool or management system to support sustainable development in industry, via the inclusion of environmental aspects such as; the use and consumption of resources and waste generated from raw material extraction and processing, production of the product, product use and final disposal of products. Properly implemented, PS offers the probability of revenue growth through product differentiation [9]. Indeed, since its early implementation in the 1970s [6], many industries, governments, multinational corporations and countries have developed and implemented PS schemes. A number of these are still in use for electric and electronic, chemical, packing and packaging, and car manufacturing. Further to this, a few product groups have successfully developed and implemented PS schemes, each of which has been implemented through voluntary or mandatory regulatory frameworks, agreed by stakeholders within the product's supply chain and lifecycle. The discourse revolves around two major aspects; responsibility and regulation, however its origin is generally attributed to three separate developments: The Responsible Care initiative by the Canadian and American chemical industry associations; the Extended Producer Responsibility (EPR) policies development around Europe; and the adaptation of PS as EPR in the US [10].

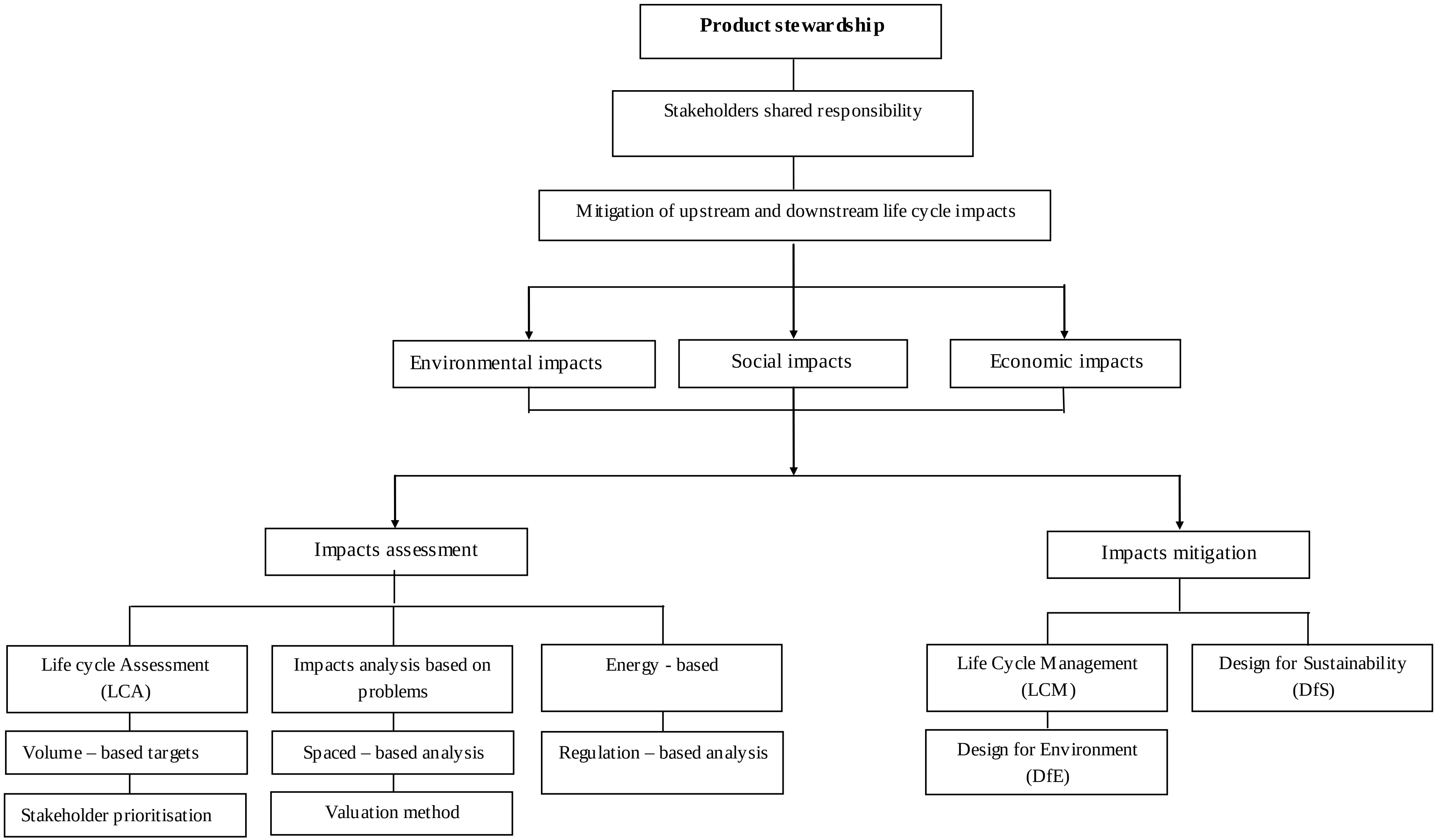

Figure 2 Product stewardship process tree from literature

Subsequent to these developments, mandatory (legislated) and voluntary PS schemes[4] have been implemented at broadly five different strategic levels; globally, continental, national, industrial and at company level as shown in Figure 3. Level 1 (global level) is concerned with an overall implementation of the scheme throughout the world by an industry, a company or several national governments. For example the Responsible Care initiative - a voluntary global initiative of the Chemical industry has a global outreach in 53 countries and applies to around 90% of global chemical production [11]. Level 2 and 3 (Continental and national levels), the OECD developed a voluntary guidance manual for national governments on EPR responsibilities and pollution control which has a predominant outreach in Europe. The Waste Electric and Electronic Equipment (WEEE) - Directive 2002/96/EC is a mandatory scheme within EU member countries has been implemented at four different levels; continental level; industry level; national level and at company levels (Level 2 - 5). Principally, PS is implemented by manufacturers and producers at company levels (Level 5) since companies have the greatest ability and responsibility [6] to make any modification or changes with regards to the environmental, health or social impacts of their products and services.

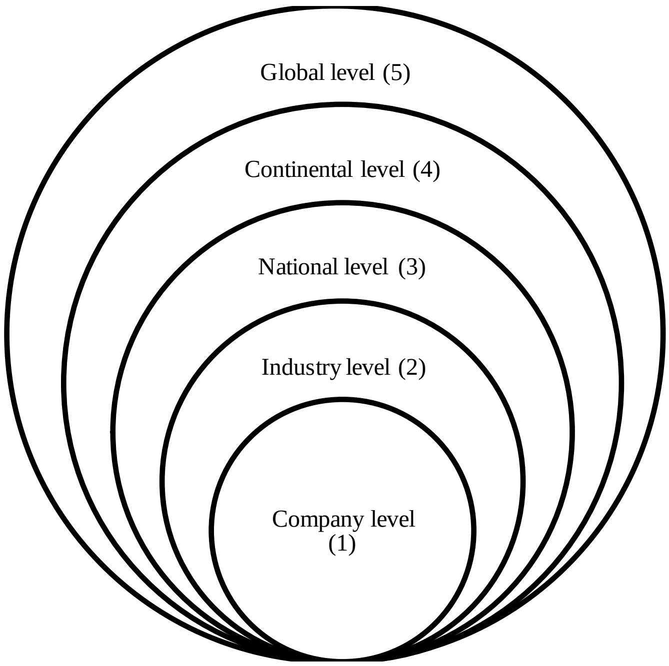

Figure 3 The strategic implementation of Product Stewardship

UK PRECAST INDUSTRY KEY PERFORMANCE INDICATORS (KPI)

Having reviewed the key components of PS, this section presents a snapshot of the UK precast concrete in the form of KPI data, collected from 2006-2010 from BPCF member companies (which account for around half of all precast production in the UK). KPI's are measures that focus on organisational performance that are key to both the current and future success of an organisation [12]. For the UK precast concrete industry, KPI are quantitative data that reflect the industry`s performance on: productivity, quality and satisfaction, resource use, health and safety, pollution, employment policies, respect for people, energy (including climate change), productivity, quality and satisfaction and emission [13], many of which are relevant to PS. The data provides both a mechanism for gauging the industry's performance over time, but also gives an overview of how social and environmental

[4] A **Scheme** can be defined as a systematic plan or arrangement for achieving a particular object or effect [15], this term will be used throughout the paper to describe all PS initiatives, projects and schemes.

impacts are being managed. Here, we present a snapshot of the industry using a series of data tables 1-11.

Table 1 Precast companies returning KPI data (2006 - 2010)

YEAR	NUMBER OF COMPANIES PROVIDING DATA	NUMBER OF PRODUCTION UNITS (Factories)	BPCF MEMBERS' REPORTED PRODUCTION (Tonnes)
2006	19	132	17,000,000
2007	25	122	19,900,000
2008	26	120	11,990,000
2009	27	135	9,300,000
2010	26	119	10,200,000

Table 2 Productivity levels

YEAR	NUMBER OF EMPLOYEES	TONNES OF CONCRETE PRODUCED PER EMPLOYEE
2006	8,309	1,648
2007	9,735	1,842
2008	8,681	1,427
2009	6,902	1,602
2010	6,732	1,516

Table 3 Quality management systems in place

YEAR	PRODUCTION COVERED BY ISO 9001 (TONNES)	PERCENTAGE OF BPCF MEMBERS REPORTED PRODUCTION
2006	14,000,000	81.5%
2007	14,300,000	80.0%
2008	10,100,000	84.5%
2009	8,200,000	87.7%
2010	9,500,000	93.1%

Table 4 Energy usage by fuel

YEAR	ENERGY USED PER TONNE OF CONCRETE PRODUCED (kWh/t)	PERCENTAGE BREAKDOWN BY FUEL SOURCE		
		Gas %	Electricity%	Gas oil or diesel%
2006	54.9	53	20	24
2007	52.9	54.5	20.7	24.8
2008	62.7	56.9	19.8	20.6
2009	67.9	47.9	16.4	35
2010	71.4	45	20.43	28.9

Table 5 Resource use – materials

YEAR	CEMENTITIOUS MATERIALS USED PER TONNE OF CONCRETE PRODUCED (/t)	AGGREGATE USED PER TONNE OF CONCRETE (/t)	PACKAGING MATERIALS USED PER TONNE OF CONCRETE PRODUCED (kg/t)
2006	0.140	0.754	3.0
2007	0.175	0.754	2.5
2008	0.130	0.832	4.89
2009	0.141	0.862	4.93
2010	0.141	0.800	4.94

Table 6 Resource use – water

YEAR	LITRES OF WATER USED PER TONNE OF CONCRETE PRODUCED (l/t)	PERCENTAGE BREAKDOWN BY SOURCE	
		Mains water	Licensed non-mains
2006	163	71	29
2007	156	70.4	29.6
2008	182.6	62	38
2009	146.7	79	21
2010	99.4	65	35

Table 7 Resource use – waste

YEAR	WASTE PER TONNE OF CONCRETE PRODUCED (kg/t)
2006	32
2007	41
2008	42.1
2009	43.7
2010	36

Table 8 Environmental management systems in place

YEAR	ISO 14000 SERIES OR EMAS (Production coverage in tonnes)	ISO 14000 SERIES OR EMAS (Percentage of production)
2006	12,900,000	75
2007	14,500,000	81
2008	10,100,000	85
2009	7,400,000	79.1
2010	9,220,000	90.3

Table 9 Average delivery distances

YEAR	AVERAGE ROAD DELIVERY PER TONNE (/t)	AVERAGE ROAD DISTANCE (MILES)
2006	27.4	108
2007	28	96
2008	18.6	122.37
2009	21.7	81.5
2010	21.8	123

Table 10 Health and Safety management systems in place

YEAR	PRODUCTION COVERED BY OHSAS 18001 HEALTH AND SAFETY (Tonnes)	PRODUCTION COVERED BY OHSAS 18001 HEALTH AND SAFETY (%)
2006	4,400,000	25
2007	4,800,000	26.7
2008	3,500,000	25.4
2009	2,700,000	39.1
2010	4,900,000	48.4

Table 11 Employment policies including training

YEAR	NUMBER OF EMPLOYEES	PERCENTAGE COVERED BY FORMAL TRAINING	AVERAGE HOURS OF TRAINING (hr/pa)
2006	8, 309	85%	12.6
2007	9,735	73%	14.1
2008	8, 681	94.1%	13.0
2009	6, 902	94.7%	7.3
2010	6, 732	98.5%	8.9

A note on environmental incidences (EI)
In 2006, 14 environmental incidences were recorded, three in 2007 and one in 2008. No data was provided for 2009 and 2010. In terms of production, in 2006, this equates to one incident per 1.2 million tonnes of concrete produced. In 2007, one incident per 6 million tonnes of concrete produced which is a significant improvement compared to 2006. In 2008, again just one incident per 10 million tonnes of concrete produced was recorded.

A note on responsible sourcing (RS)
Responsible sourcing of materials for precast concrete production is key to the achievement of PS within the industry. RS can be verified through an ethos of good supply chain management and PS [14]. In 2009, 39% of the industry's production (tonnes) was covered by BES 6001 certification and in 2010 this increased to 67.4% for the industry and a 65.29% of all production sites.

PRECAST MANUFACTURERS' ATTITUDES TOWARDS PRODUCT STEWARDSHIP

To gauge the industry's understanding on PS and its possible application within the industry, senior-level/executive staff from 12 members of the UK precast concrete industry were invited to take part in semi-structured interviews, an overview of which is provided in this section. The objectives were to: explore the feasibility and acceptability of PS implementation; obtain feedback on effective means and methods of developing consensus and facilitating progress; understand the current industry's perception and understanding of the term 'product stewardship', its importance, benefits, application within companies, areas of focus, operation and the possibility of part or whole scale future implementation of PS; and the most effective means of building consensus on PS in the UK precast concrete industry. A two-part interview schedule was developed to cover the aforementioned topics using a range of open and closed-ended questions.

Of the 12 respondents that took part in the survey, three were company directors; three Health Safety and Environment (HSE) Managers; two process managers, one head of sustainability, two environment leaders/ advisors, one process design manager and one precast design manager. The interviewees were sufficiently experienced and qualified to take part due to their experience and knowledge of sustainable construction and there was consistency observed in responses on completion of the 12 interviews, indicating sample validity. The 12 companies that took part in the survey account for approximately 55% of the UK precast industry's production (i.e. 5,433,912 tonnes), so can be said to be representative of the sector. Table 12 shows that a range of company sizes were targeted to ensure that the sample accounted for the viewpoints of large, medium and small businesses.

Table 12 Interview programme – participating companies by size

GROUPS	PRODUCTION CAPACITY (Tonnes)	NUMBER OF INTERVIEWEES
Group A (Small size)	≤ 100, 000	5
Group B (Medium size)	≥ 100, 000 to ≥ 500, 000	4
Group C (Large size)	≥ 500,000 to ≥ 1, 000, 000	3

While there was a broadly consistent understanding of what PS might mean for precast concrete manufacturers, the company representatives appeared to have slightly different interpretations of PS, depending on their company's size and the individual's familiarity with key concepts such as RS and life-cycle management. Example definitions from each group are shown below:

Group A: *"Keep control on the main source ingredient which is concrete. That it is responsibly sourced."*
Group B: *"Everybody involved in the design, manufacture, installation and operation of a product has a responsibility somewhere along the chain .Taking responsibility by all key stakeholders for management of impacts".*
Group C: *"Encompassing full Life Cycle Assessment, Life Cycle Costing including use phase and responsibility taking at every bit of the building, building regulations, selling use, and end-of-life. It includes design for reusability, design for recycling, closing the loop, and cradle-to-cradle."*

All the companies thought PS was 'important', with one or two saying it was 'very important' and one suggesting that it would 'become more important'. The benefits were thought to centre on cost savings, efficiency savings and being seen to be 'doing the right thing'. The interviewees described a range of initiatives that they thought constituted important evidence of their participation in PS-type activities, such as 'a sustainability assessment framework' and 'Fairtrade' type ethical trading standards, but only a minority were actively participating in these. That said, there was extensive membership of established management system standards such as ISO 9001, ISO 14001 and OHSAS 18001 and the recently established RS certificate, BES 6001 [14]. While many spoke of the importance of a 'life-cycle attitude', it appeared that only the larger companies had obtained full life-cycle assessments for their products. Overall, the interviewees said that any PS scheme for the precast industry should integrate with existing practices and initiatives, and would probably be best managed through one of the key trade associations, like BPCF. They also suggested that any PS initiative by the industry should start voluntarily and later be made mandatory, and at least should take 1-2 years from before it comes into effect.

CONCLUSION

There is a clear case that a PS scheme could have potential to help the UK precast concrete industry further its sustainability activities, but the KPI data and evidence from industry leaders presented here suggests that companies are at different levels of understanding, participation and aspiration. The interviewees understood the basic premise of PS and recognised that it can offer benefits to their respective companies and potentially the industry in general. With a growing number of companies investing in life-cycle assessments of their products (in readiness for Type III EPDs), it is plausible that the first phase of a PS scheme would be to develop a life-cycle management strategy for the industry. In this way, the existing knowledge of manufacturers could be leveraged to gradually encompass other components of a fully-fledged PS scheme. That said, the interviewees urged caution owing to the difficult economic circumstances and highly competitive market that they currently face in the UK.

This paper has demonstrated the key sustainability performance of the UK precast concrete industry from 2006 – 2010. There are clear evidences to show the precast concrete industry's ability to capture and analyse state of the art data which can serve as a major step in helping towards present and future performance measurement, monitoring and improvements.

ACKNOWLEDGEMENTS

Special thanks goes to Loughborough University, British Precast Concrete Federation and to all member companies of the federation that have submitted data from 2006- 2010 and to all the individuals and companies that gave their time and helped in the research.Without all their support this research would not have been carried out.

REFERENCES

1. HOLTON I, GLASS J AND PRICE A. *Managing for sustainability: findings from four company case studies in the UK precast concrete industry*. Journal of Cleaner Production. Vol. 18, 2009, pp 152-160.
2. ALIYU A A, GLASS J, CLARKE, M A, ELHAG, H K, PRICE A D F, *The need for a product stewardship scheme to improve sustainability in the UK precast concrete industry*, Responsible Leadership. Proceedings of the Corporate Responsibility Research (CRR) Conference, University of Vaasa, Vaasa (Finland), Ed. Ketola T., 2009, pp 1-17.
3. DEPARTMENT FOR BUSINESS, ENTERPRISE AND REGULATORY REFORM. *Strategy for Sustainable Construction*. London: BERR; 2008.
4. EUROPEAN UNION. *The European Construction Sector*. [Online] available at: http://ec.europa.eu/enterprise/sectors/construction/index_en.htm [Accessed on: 11th August, 2011].
5. KREITH F, AND TCHOBANOGLOUS G. *Handbook of solid waste management*. McGraw - Hill Professional. 2002. Second ed. New York; London.
6. UNITED STATES ENVIRONMENTAL PROTECTION AGENCY. *What is Product Stewardship?* [Online] available at: http://www.epa.gov/epawaste/partnerships/stewardship/basic.htm. [Accessed on: 10th August, 2011].
7. JOHNEN B, FOSTER L AND THOMAS M. *Stewardship in the Agrochemical Industry.Zeneca Agrochemicals*. 2000. [Online] available at: http://www.rsc.org/delivery/_ArticleLinking/DisplayArticleForFree.cfm?doi=b006246o&JournalCode=PO; [Accessed on: 13th July, 2009].
8. BRADY K, HENSON P, FAVA, J A. Sustainability, Eco -efficiency, Life cycle management, and Business Strategy. Environmental Quality Management. Vol. 8, No. 3, 1999, pp 33-41.
9. HART S L. *Capitalism at the crossroads: aligning business, earth, and humanity*. Wharton School Publishing, 2007. Upper Saddle River, New Jersey.

10. LEWIS, H. *Defining product stewardship and sustainability in the Australian packaging industry*.Environmental Science and Policy. Vol. 8, No. 1, 2005, pp 45-55.

11. RESPONSIBLE CARE. *Responsible Care Global Charter*. [Online] available online at: http://www.responsiblecare.org/page.asp?p=6341&l=1; [Accessed: 21st February, 2010].

12. PARMENTER, D. *Key performance indicators: developing, implementing, and using winning KPIs*. 2007. John Wiley and Sons, New Jersey. [Online] Available at: http://reader.eblib.com/. [Accessed on 13th July, 2011].

13. BRITISH PRECAST. *Sustainability Matters – Precast 2011 update edition*.[Online] accessed: 18th July, 2011. Available at: http://www.britishprecast.org/documents/BPCFSustainabilityMattersPRECAST2011updateMay2011.pdf.

14. ANDERSON J, SHIERS, D AND STEELE, K. *The Green Guide to specification*. 2009. Fourth edition. BRE, Oxford University and Wiley Blackwell, p 9.

15. SOANES C AND STEVENSON A. Concise Oxford English Dictionary. Eleventh edition. Oxford University Press, Oxford, 2009.

APPENDIX C Paper 3

Reference: Aliyu, A. A, Glass, J., Clarke, M. A, Elhag, H. K and Price, A.D.F. (2012). Conceptual and structural components of product stewardship in the precast concrete industry. International Journal of Sustainable Construction. (In press 2013, Vol.2 Issue 1).

Conceptual and structural components of product stewardship in the UK precast concrete industry

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Abstract

Purpose: Waste minimisation, carbon, water use and energy use reduction targets emanating from industry and government have driven a range of production and process improvements in the UK precast concrete industry. The industry's own sustainability strategy 'More from Less' has provided a coherent overarching approach, but it is argued that by adopting the concept of product stewardship (PS), the industry may be able to make further, more substantial step changes to its environmental key performance indicators (KPIs). This research deploys social survey methods to identify and discuss the UK precast industry's attitudes towards conceptual and structural components of PS, from a sample of 12 companies.

Design/methodology/approach: Following a literature review and identification of two new models to depict the conceptual and structural components of PS, the results of a questionnaire survey and a series of personal interviews with senior staff are presented, based on 12 precast concrete manufacturing companies (accounting for 66% of the UK precast industry's total output in 2010). This paper discusses these results in the context of impacts, stakeholder responsibilities, drivers and barriers and mechanisms for implementation).

Findings: For the UK precast concrete industry, product stewardship is thought to be best described by a combination of life-cycle (impacts) management; shared stakeholder responsibility and the responsible sourcing of materials, underpinned by robust environmental management systems. This aligns fairly well with existing understandings of PS, but there are specific outcomes for this industry: designers and manufacturers are found to be responsible for the majority of sustainability impacts, confirming the need for a through-life approach; a combination of drivers is likely to propel the development of a PS scheme; and if so, the mechanism of a voluntary PS scheme, managed by a trade association, would be an appropriate starting point.

Originality/value: The research is the first to critically consider the development path for PS in a UK construction materials industry context. It draws conclusions about impacts, stakeholder responsibilities, drivers and barriers and mechanisms. It provides a sound basis from which the precast concrete industry could develop a sector-wide approach to PS, such that precast manufacturing companies can further improve performance against key environmental and social indicators and so enhance their competitiveness.

Keywords:

Environmental management; manufacturing; precast concrete; product stewardship; research; sustainability; sustainable construction.

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Introduction

In 2004, the UK precast concrete industry devised a sustainability programme 'More from less' to help its member companies understand and incorporate sustainability principles within manufacturing, operations and related activities. It planned to do this ostensibly through performance measurement against key environmental, social and economic indicators, supported by advice on interventions at manufacturing facilities to improve performance. Further to this, a coherent sector sustainability strategy was developed and launched in 2008 (Holton *et al.,* 2010) and the industry's trade association (the British Precast Concrete Federation, BPCF) then embarked on an R&D programme to investigate the potential offered by implementing the principles of product stewardship (PS) as another means of improving performance and ultimately competitiveness. This paper reports on research to explore the industry's attitudes towards PS. It discusses the UK precast concrete industry's current approach towards sustainability and its key performance indicators (KPIs), then defines product stewardship and explores its potential alignment with precast concrete manufacturing. Following a description of the research methods used, the paper presents an analysis of results from a survey of 12 precast concrete manufacturers and comes to a close by presenting conclusions pertaining to the future development of PS in the precast industry.

The nature of the UK precast concrete industry

The UK precast concrete industry's roots can be traced to the end of the 19^{th} century when engineers and builders recognised the quality and economic advantages offered by casting concrete with the use of machines (Clarke and Glass, 2008). In 2010, the UK precast concrete industry's annual production stood at over 36 million tonnes, which is worth in excess of £2 billion (Holton *et al.,* 2010) and there are thought to be over 800 precast concrete companies in the UK (Sustainable Concrete, 2010), with around 22,000 employees (BIBM, 2008), although not all companies belong to the industry trade body (BPCF). The UK precast concrete industry is part of the construction products industry and by extension the construction industry, which includes building, civil engineering, construction materials and products, and associated services (Holton *et al.,* 2008). According to the Construction Products Association (CPA), the largest amongst those four different, but related, activities is construction materials and products, which has a total annual turnover of more than £40 billion (CPA, 2009). Of course, all this sits within the broader construction industry which employs 7% of the UK population (CPA, 2009), and accounts for 8% of Gross Domestic Product (GDP). Hence, the literature correctly identifies the strategic economic importance of the construction industry and its sub-sectors, such as product manufacturing, but it is equally clear that the construction, development and use of the built environment has associated sustainability impacts, such as energy use, water consumption, waste generation and particulate emissions. The 2008 Strategy for Sustainable Construction (BERR, 2008), a joint industry and government document, identifies a series of targets in respect of these impacts, such that the construction industry could contribute to the UK's overarching sustainability targets.

Within this broader context, the next section presents an analysis of the UK precast concrete industry's key sustainability impacts.

The precast concrete industry's key sustainability impacts

Regardless of production/placing method (i.e. in-situ, precast), concrete's key environmental and social impacts can be considered as occurring across six main stages, based on its life-cycle (Optimat, 2008):

1. raw material extraction;
2. cement and addition manufacture;
3. production of ready mixed concrete and precast products;
4. construction of buildings and infrastructure using concrete;
5. operational use in the built environment; and;
6. end-of- life disposal and recovery.

Yet finding ways and methods to reduce the environmental impact of the UK's entire concrete industry has proved to be a major challenge (Parrott, 2002). This is due to the complexity of accounting for its life-cycle emissions, such as CO_2, SO_X, NO_X etc (Bijen, 2002), but the last decade has created a better understanding of concrete's environmental impacts in the context of the entire UK (see Figures 1 and 2).

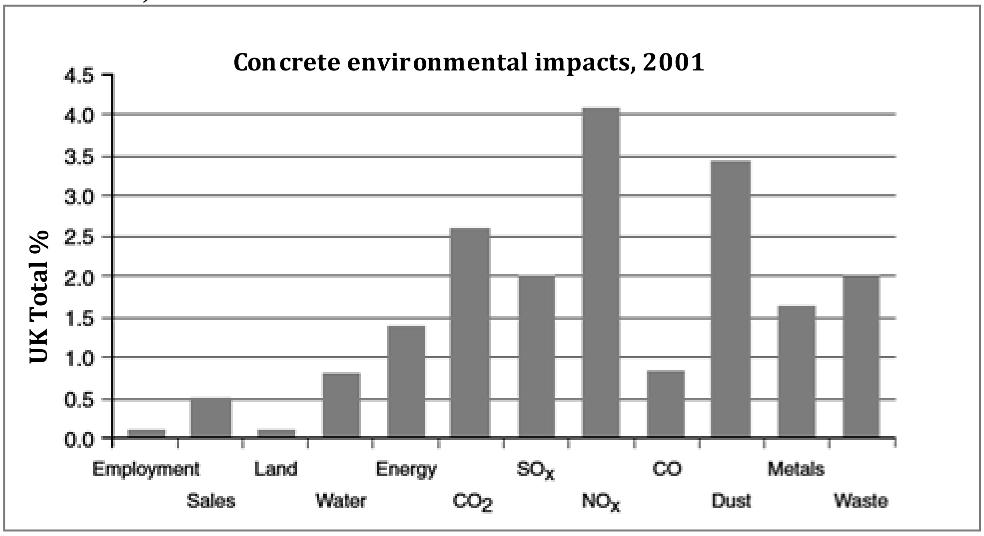

Figure 1: Percentage of UK environmental factors connected to concrete production (Concrete Society, 2001).

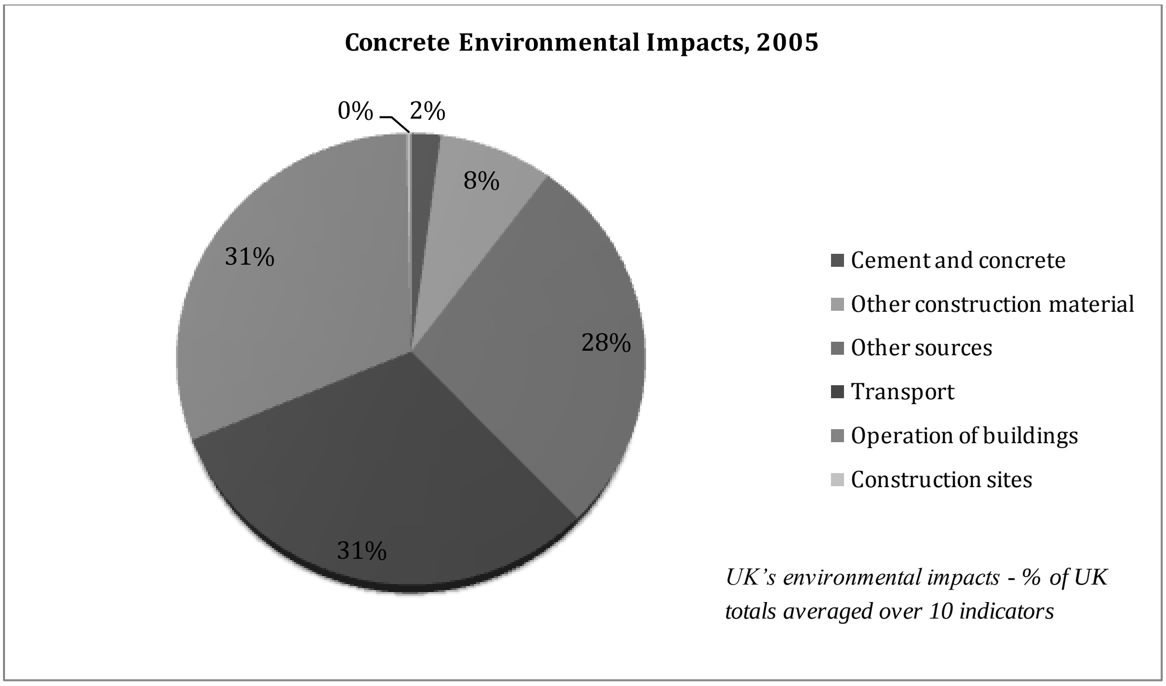

Figure 2: Concrete's environmental impacts (The Concrete Centre, 2005, p. 3)

The list of impacts shown in Figures 1 and 2 are broadly applicable to all concrete types (including precast concrete products), but there are significant variations in numerical values for specific concrete products, for instance related to cement content and curing regimes (Elhag et al 2008); as a result, caution should be exercised in extrapolating specific values from one part of the concrete industry to another. That said, without doubt the largest source of concrete's CO_2 emissions arise from the inclusion of Portland cement in the product (Sakai, 2008), which is energy-intensive in its manufacture. This is also consistent for precast concrete, although transportation does assume a slightly greater proportion of precast concrete's impacts, compared to ready-mixed concrete (Bijen, 2002). So, more specifically, the major sustainability impacts associated with precast concrete products are its embodied environmental impacts (resulting from constituent precast raw materials, precast manufacturing, energy consumption, physical waste) (Elhag*et.al*, 2008), but beyond that, other key sustainability issues faced by the UK precast industry have been identified by Holton *et al* (2010), who grouped them into the 'triple bottom line' of sustainability impacts (i.e. environmental, social and economic) (after Elkington,1997); see Table 1.

Table 1: Key environmental, social and economic impacts of precast production (Holton et al., 2010).

Environmental impacts	Energy, including Climate Change Resource use (materials, resource use, water, waste) Pollution/emissions including transport Biodiversity
Social impacts	Health and safety Employment policies including training Respect for people and their local environment Contribution to the built environment Local communities and employees
Economic impacts	Productivity Competition Penalties and liabilities Profitability

Within this context, the precast concrete industry has made progress in measuring these key impacts through key performance indicators (KPI) data collection and analysis. Since 2006, sustainability charter signatory companies of British Precast have been submitting data to show their performance against industry average data which includes, for example; energy use, water use, waste and use of management systems. According to Aliyu et al (2012), 9.5 million tonnes of reported production was covered by ISO 9001 UKAS certified quality management system or a recognised manufacturers quality assurance scheme in 2010, up from 8.2 million tonne coverage in 2008. Improvements were also recorded with water; in 2006, water used per tonne was 163l/t (of 17 million tonnes of concrete produced). In 2010, the figure stood at 99.4l/t (of around 10 million tonnes production). Table 2 shows a summary of KPI data for 2006-2010.

The UK precast concrete industry has therefore begun to measure and reduce its impacts, but it is argued that the industry needs a step change in the mitigation of its key impacts, which could be achieved through adopting a more holistic supply chain initiative, from a life cycle point of view. Product stewardship offers such an approach, and is described in the next section.

Table 2: A summary of Key Performance Indicators data from 2006 – 2010 (After Aliyu et al., 2012)

Year	Number of companies providing data	Number of production units (factories)	BPCF members' reported production (tonnes)	Number of employees	Energy used per tonne of concrete produced (kWh/t)	Litres of water used per tonne of concrete produced (l/t)	Waste per tonne of concrete produced (/t)
2006	19	132	17,000,000	8,309	54.9	163	32
2007	25	122	19,900,000	9,735	52.9	156	41
2008	26	120	11,990,000	8,681	62.7	182.6	42.1
2009	27	135	9,300,000	6,902	67.9	146.7	43.7
2010	26	119	10,200,000	6,732	71.4	99.4	36.0

Year	Production covered by ISO 9001 (tonnes)	Percentage of BPCF members reported production	Cementitious materials used per tonne of concrete produced (/t)	ISO 14000 series or EMAS (Production coverage in tonnes)	ISO 14000 series or EMAS (Percentage of production)	Production covered by OHSAS 18001 Health and Safety (tonnes)	Production covered by OHSAS 18001 Health and Safety (%)	Percentage covered by formal training
2006	14,000,000	81.5%	0.140	12,900,000	75	4,400,000	25%	85%
2007	14,300,000	80.0%	0.175	14,500,000	81	4,800,000	26.7%	73%
2008	10,100,000	84.5%	0.130	10,100,000	85	3,500,000	25.4%	94.1%
2009	8,200,000	87.7%	0.141	7,400,000	79.1	2,700,000	39.1%	94.7%
2010	9,500,000	93.1%	0.141	9,220,000	90.3	4,900,000	48.4%	98.5%

Product stewardship

The term product stewardship (PS) was first coined in 1972 by Dow Chemical Company (Rainey, 2006; Lipmann, 2009) and in the intervening period developed into a mature concept for managing environmental impacts, often, but not exclusively, within an industry setting. PS schemes are in use by a range of industries, groups, governments for different products including: the electric and electronic industries, chemical industries, packing and packaging industries, car industries (Aliyu et al., 2009). Further to this, specific product industries have successfully developed and implemented PS schemes, each of which has been implemented through voluntary or mandatory regulatory frameworks, agreed by stakeholders within the product's supply chain and lifecycle.

The PS discourse in literature revolves around two major aspects; responsibility and regulation (Lewis, 2005), however its origin is generally attributed to three separate developments (The Responsible Care initiative by the Canadian and American chemical industry associations; the European Extended Producer Responsibility (EPR) policies; and, the adaptation of PS as EPR in the USA). In fact, the drivers for companies to engage in PS are quite varied; these include: revenue growth through product differentiation (Hart, 1997); to avoid being vulnerable in the future, (Armstrong and Kotler, 2006); to become more responsible through proper ethical management (Johnen et al., 2000); and, to reduce cost and liabilities (Johnen et al., 2000).

PS is conceptualised as a part of the environmental management discipline (NWPSC, 2011; Lewis, 2005), with a focus on reducing the environmental impact of products by sharing responsibility for so doing among all those in the product life-cycle (i.e. manufacturers, retailers, users, and disposers) (UNEPA, 2011; Hill, 2010; Bruijn, 2007; Madu, 2007). Hence, PS is broadly conceived as a means to support sustainable development (Kreith and Tchobanoglous, 2002), via the inclusion of environmental aspects (such as the use and consumption of resources and waste generated from raw material extraction and processing, production of the product, product use and final disposal of products) (Brady *et al.*, 1999). PS is characterised and institutionalised through for example, a comprehensive framework, management system or initiative to address and help reduce all impacts and risks associated with a product throughout its entire lifecycle (PSF, 2011; PSI, 2011; Hart, 2007; Hickle and Sititzhal, 2003). All that said, PS has consistently lacked a single unified definition; this is a contested subject and understandings vary between companies, sectors and countries.

Looking in more detail, Adams (2010) argues that there are 10 key principles to achieving PS, regardless of the product in question:

1. Shared responsibility
2. Life cycle thinking
3. Knowledge

4. Supply chain communication
5. Stakeholders
6. Teamwork
7. Awareness
8. Innovation
9. Management
10. Integration

While attractive in its simplicity, this list does not thoroughly capture the breadth of conceptual and structural nuances of PS. So, based on literature, two new models are presented here: the key, generic conceptual components of PS are shown in Figure 3 and the key, generic structural components are shown in Figure 4.

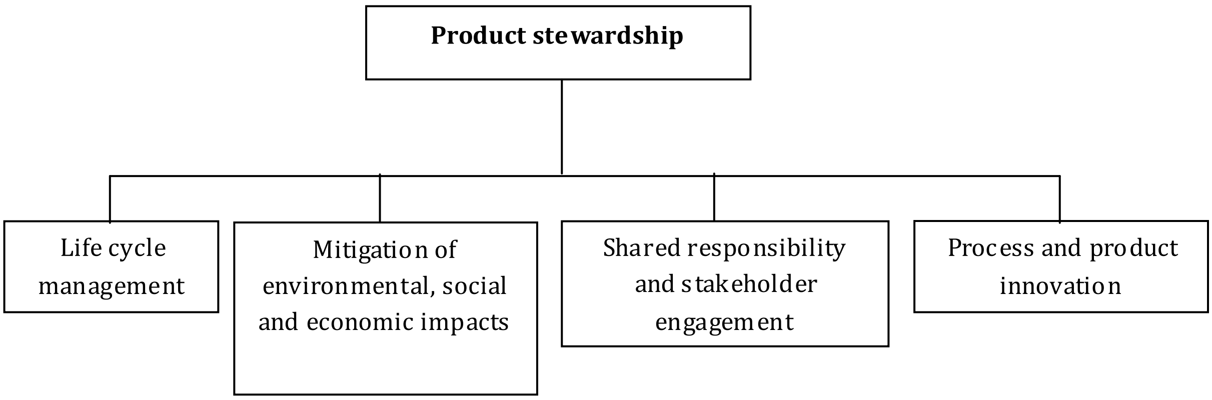

Figure 3: Key conceptual components of product stewardship (after Aliyu et al., 2009).

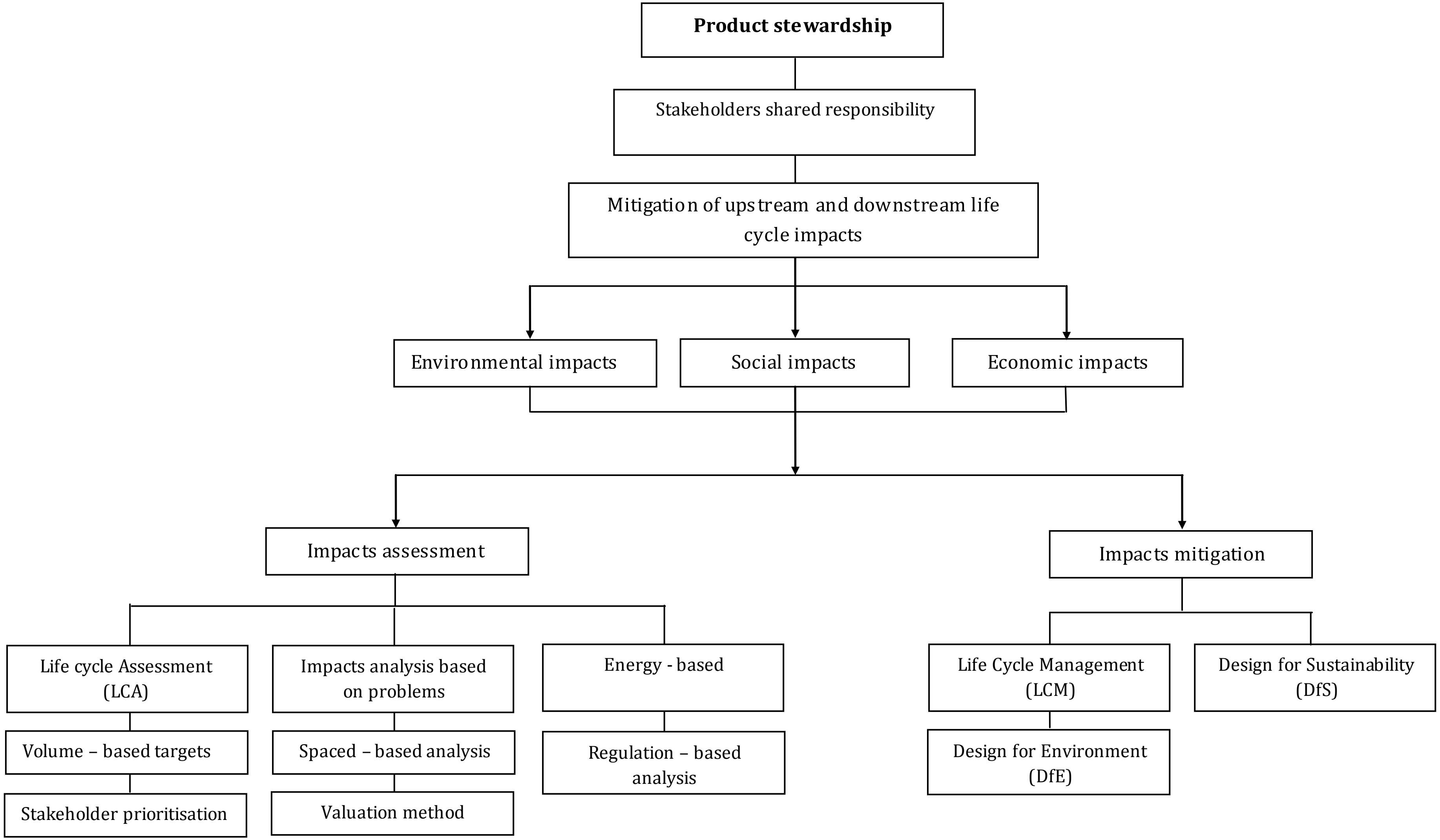

Figure 4: Key structural components of product stewardship (after Aliyu et al., 2009).

A problem and an opportunity

The UK precast concrete industry, like all sub-sectors of the construction industry has been found to be under pressure from government, clients and other stakeholders to reduce its sustainability impacts. The precast industry has understandably focused on reducing its major (often environmental) impacts and has established an effective methodology for tracking progress against a set of KPIs, but the sector could benefit from a step change in how companies manage and reduce their impacts. It is plausible that product stewardship might offer a long-term framework for the precast industry to do so, but so far the concept, principles and practices encompassed by product stewardship have not been implemented at all within the construction products industry in the UK or elsewhere (unlike the oil and gas, chemicals, automobile. packing and packaging industries). Hence, there is an early opportunity to identify the development path that PS in the construction products sector, in this case in the context of the UK precast concrete industry. Research is needed to identify the drivers, enablers and barriers associated with such a change and a first step in so doing is to collect and analyse the views of the UK precast industry in respect of PS, in the context of the new generic models for PS shown in Figures 3 and 4. To seek such an industry understanding of the character, structure and possible implementation of PS in the precast industry, a research survey and interviews were conducted, as described in the next section.

Research methodology

The aim of the research was to collect a sample of views from manufacturers within the UK precast concrete industry, to understand its level of awareness and understanding of PS and broadly assess the potential for the successful implementation of PS in this sector. The specific objectives of the research (in the context of the UK precast concrete industry) were, to:

- define and depict an industry-specific interpretation of PS;
- identify drivers and barriers to implementing a PS scheme; and,
- identify any key components and enabling mechanisms for doing so.

Based on evidence from a comprehensive review of literature and industry reports, factory visits and a review of industry sustainability KPI data, these research objectives were translated into a number of research questions, suitable for use in a social survey and/or personal interviews with selected UK precast concrete manufacturers. The initial set of questions (including a range of Likert scale, closed-ended and open-ended questions) were tested through a pilot study with two companies. Following the pilot exercise, a few more questions were added to enhance the quality and depth of the research instrument and ease completion by the subject. At this point it was also confirmed that the data collection would comprise two sets of data, firstly using a self-completion questionnaire and secondly using a semi-structured personal interview schedule. Haigh (2008) notes that qualitative interviews potentially help researchers to *"generate insights, concepts and expand understanding",* but a combination of semi-structured interviews with a self-completion questionnaire can be used to gain a better understanding on a given subject (Bryman and Bell, 2011). The self-completion questionnaire focused on:

- identifying the current status of the sustainability initiatives of the industry;
- examining the extent to which the current life-cycle management of the precast concrete industry is suitable and sustainable;
- apportioning of key sustainability impacts to supply chain stakeholders;
- management of key environmental, social and economic impacts; and,
- identification of drivers, barriers and challenges for initiating change within the UK precast concrete industry.

For questions using a Likert scale, a weighting factor was used in order to attribute greater value to the higher scores and so get a better understanding of the pattern of responses. A weighting factor was applied as shown in Table 3. So, for example, with a total of 12 respondents, the maximum possible score for any such question would be 12 'votes' for 'Extremely important', which is weighted at 5, hence scores are shown out of 60. This method provides a proxy 'approval rating' for each option shown as a percentage value for ease of comparison.

Table 3: Weighting factors used in analysis of Likert questions.

Scoring scale (Likert)	**1 = Not important**	**2 = Fairly important**	**3 = Important**	**4 = Strongly important**	**5 = Extremely important**
Weighting factor	1	2	3	4	5

The semi-structured interview instrument focused on:

- understanding of PS, its importance, benefits, individual company involvement in PS and management systems and life-cycle assessment (LCA);
- what more can the industry do to mitigate its key environmental, social and economic impacts; and,
- contents of a UK precast concrete industry PS scheme, its leadership, possible implementation and the most effective means of building consensus amongst stakeholders.

In accordance with the strategy above, the final interview questions were designed to probe answers from the self-completion questionnaire. For example, in the questionnaire a Likert scale question was asked on the extent to which current life-cycle management (LCM) methods of precast concrete products are suitable and sustainable. Then, follow-up questions were asked during the interviews, e.g. on the policy or system put in place to mitigate life-cycle impacts; balancing of sustainability requirements; and steps taken by companies on embodied or inherited impacts upstream and downstream. Where appropriate, interviewees were also shown examples of PS schemes from other industries to help them provide responses.

The rationale for the selection of companies for the research was that the sample should:

1. represent the full range of precast product types manufactured in the UK;
2. include a range of small, medium and large size companies, by turnover and head count; and,
3. account for the majority of the UK precast industry's total output, by volume and value.

Based on the criteria above, sixteen companies within the UK precast concrete industry were identified and invited to take part in the research between February-April 2011, each received a formal letter which was followed up by a phone call to reassure participants and clarify details. Twelve companies opted to take part and each identified a suitable person to act as their representative – these individuals were sent a copy of the self-completion questionnaire in advance of the interviews. The twelve semi-structured interviews were conducted either within the premises of the respective companies that took part in the survey or at other convenient locations. The next section presents the results of the twelve questionnaires and interviews.

Results and analysis

This section provides an overview of the key results of the questionnaires and interviews, using a combination of textual descriptions (of open-ended questions) and basic arithmetical and ranking analyses of quantitative questions.

Profile of the respondents' companies

The twelve UK precast concrete companies which took part in the research produce in excess of over 6.7m tonnes of precast concrete products, and represent the full range of precast products made in the UK. Based on the EU definition of business sizes[5], three companies could be classed as large (based on both turnover and head count), while eight could be classed as medium-sized and one as a small-sized company (hence nine can be classed as SMEs). Turnover is not reproduced here owing to commercial sensitivities, but Table 4 does show the respondent companies classified by headcount against the EU definition.

[5]The category of micro, small and medium-sized enterprises (SMEs) is made up of enterprises which employ fewer than 250 persons and which have an annual turnover not exceeding 50 million euro, and/or an annual balance sheet total not exceeding 43 million euro (extract from Article 2 of the Annex of Recommendation 2003/361/EC).

Table 4: Categorisation of respondent companies' size.

Categorisation of companies based on the EU SME Definition		
Company category	Staff Headcount (number of persons expressed in annual work units)	Number of companies
Large – sized	Over 250	3
Medium – sized	< 250	8
Small	< 50	1
Micro	< 10	0
Total		12

The roles of individual respondents ranged from company director, environment advisor/ leader, head of sustainability, head of HSE, HSE manager, process systems manager and precast design manager; seniority ranged from director level to middle management level staff.

Current methods for the 'Life Cycle Management' (LCM) of precast concrete products

This question was aimed at understanding the life-cycle management methods currently used by precast concrete manufacturers. LCM is a key structural component of PS, as shown earlier in Figure 2. All 12 companies provided responses to seven pre-selected LCM methods, identified from literature and industry documents; the results are shown in Table 5 (which includes a ranking, percentage and score out of a maximum possible 60). Clearly recycling is perceived as the most commonly used approach (with the highest approval rating), with life-cycle assessment also seen as an important tool (considered in more detail in the next question).

Table 5: Weighted scores and ranked list of life-cycle management methods.

Life-cycle methods	Weighted score	Percentage 'approval rating'	Rank
Recycling	46/60	77%	1
Life cycle assessment	39/60	65%	2=
Life cycle costing	39/60	65%	2=
Material recovery	33/60	55%	4
Reuse	32/60	55%	5

Material collection	27/60	45%	6
Take back	20/60	33%	7
Other (raw material supply was cited by a single respondent)	4/60	6%	8

Life-cycle assessment (LCA) of products

Respondents were asked whether or not their organisations had considered using an independent third party recognised LCA of their products either fully or for part of their operation(s). ISO 14040:2006 argues that LCA *"addresses the environmental aspects and potential environmental impacts (e.g. use of resources and the environmental consequences of releases) throughout a product's life cycle from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal (i.e. cradle-to-grave)"*. Learning from examples within the building industry, Horne *et.al* (2009, p.19) elaborates that the Concrete Industry Association (CIA), the brick and tile industry in Australia have conducted LCA studies to identify and address these key issues. The CIA has already developed inventories on concrete and cement. The question further asked for an explanation of the drivers behind the decision to commission an LCA study. Eight of the respondents (including all the SMEs) said that they had considered or were considering using an independent third party recognised assessor for all or part of their products and services. Two SMEs and one non-SME already had certified LCAs (for all landscaping products and pipes products), but cost was cited as a barrier to wider participation. Some of the benefits cited by these companies include; LCA had helped them in data capture on key hot spots and cold spots within their manufacturing process, it served as a learning curve with regards to energy use, transportation, cement content. However, the non SME company raised concerns regarding the understanding of LCA amongst clients as well as it being expensive to carry out for small companies.

This level of participation is similar to that found by Horne *et.al* (2009, p.19) who examined uptake of LCA in the brick and tile industry.

Apportioning sustainability impacts through stakeholder responsibility

Respondents were asked about the extent to which designers, suppliers, contractors, clients, manufacturers, government, users or others) have a stake in the sustainability impacts of the precast concrete industry. These stakeholders are involved in the design, production, construction/ installation, use, maintenance and end-of-life of precast concrete products (Safety, Health and Environment (SHE) Manager of a medium sized company based in East Midlands that specialises in the manufacture of precast concrete ground beams, pile foundations, walls e.t.c), yet apportioning the extent to which each has a responsibility, has not yet been established in the construction literature. This is a critical gap; Lewis (2005) and Adams (2011), argues that stakeholder involvement and share is a vital component in successful product stewardship schemes, yet surely this should be reflective of relative impacts.

While one respondent (A SHE manager of a medium sized company and a pipe manufacturer located in the East Midlands) suggested: *"Everybody involved in the design, manufacture, installation and operation of a product has a responsibility somewhere along the chain",* it was clear from the sum of the responses that designers and manufacturers were thought to be the most important stakeholders, as shown in Figure 5. One can infer that this asymmetry should be taken into account in the development of a PS scheme for precast concrete, but this initial outcome warrants further investigation.

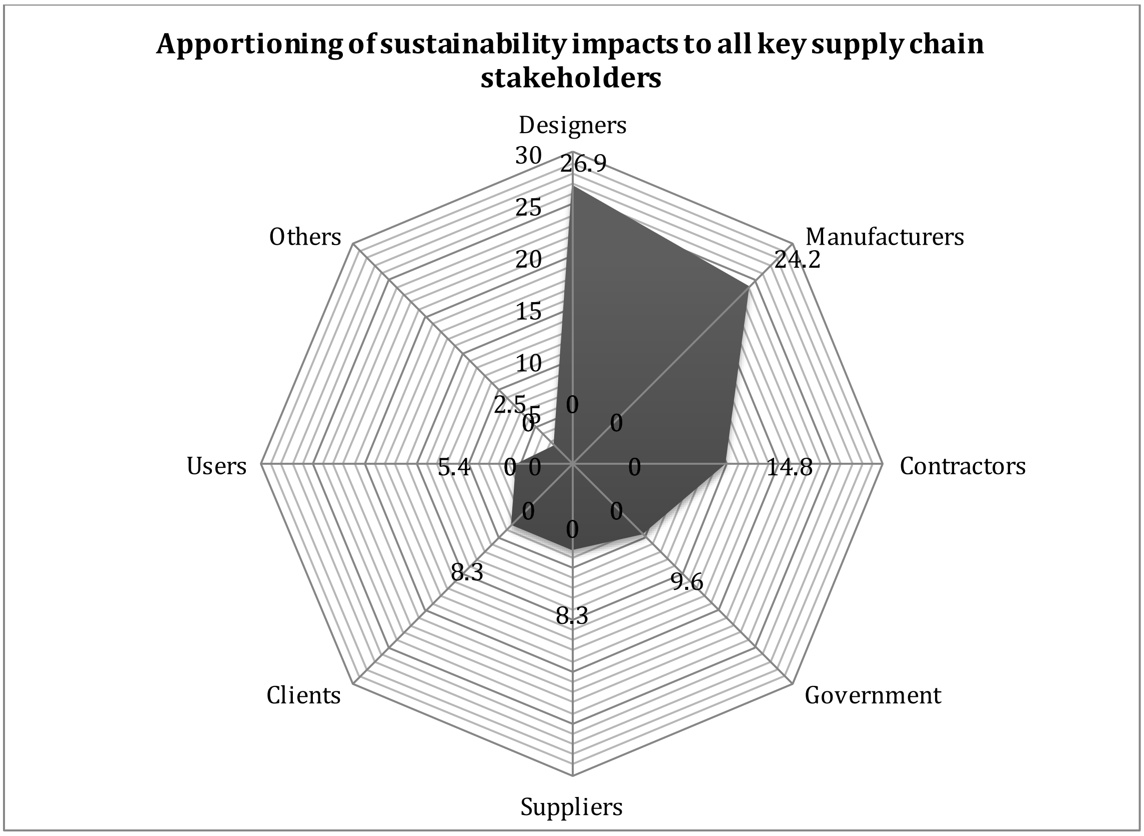

Figure 5: Asymmetry in stakeholder impacts and responsibilities in the precast concrete supply-chain.

Sustainability management – decomposition into key issues

Based on the precast concrete industry's key performance indicator categories and the structural model for PS shown in Figure 4, three questions were developed to explore key aspects of sustainability management, in the manufacturing setting. There seems to be agreement on the key elements of sustainability management within literature, for example, Hopwood et al (2005) suggests that sustainability is about 'a range of environmental issues with socio-economic issues' and Carter and Rogers, (2008) made a clear link between environmental, social and economic goals, but believe that many companies implement environmental and social plans or strategies in a fragmented and disconnected way. Burke and Gaughran (2007) suggest that a key step towards sustainability is the attainment of ISO140001 and other standards such as ISO9001 and OHSAS18001. That said, Lozano (2008) and Lozano and Huisingh (2011) warn that the social, economic and environmental aspects of sustainability interact with each other, and should be measured in an inter-linked manner, but this requires a mature and sophisticated approach to sustainability reporting which is lacking in many companies.

Given the above context, in this case, a set of questions was posed around environmental, social and economic matters, each decomposed into specific aspects relating to precast concrete manufacture. The results generally depict high approval ratings for the named issues, which confirms their relevance to companies within the industry and hence corroborates their inclusion in the industry's KPI dataset. Respondents were invited to suggest other issues, but none were cited.

Environmental issues

Here, respondents were asked about the value of environmental management systems (EMS), e.g. working to BS 8555: 2003 or ISO 14001: 2006, because literature identifies clearly the value of EMS as a platform for sustainability improvements within manufacturing companies (e.g. Holton et al (2010); Curkovic and Sroufe (2011:87) maintain that standards like 14001 give 'significant benefits internally and externally' and in the right hands can be a tool for sustainability in the supply chain, but do not ensure a level playing field. A further set of specific environmental impacts were then listed and respondents were asked to rank these on the Likert scale as before. Table 6 presents the results and shows that the use of an Environmental Management System is considered of utmost importance (with an approval rating of 55/60, or 92% confirming similar results in the literature); Waste Minimisation and Embodied impacts (e.g. from cement) at 75% and CO_2 emissions are also highly regarded.

Table 6: Weighted scores and ranked list of environmental aspects.

Environmental issues management	Weighted score	Percentage 'approval rating'	Rank
Environmental management systems	55/60	92%	1
Waste minimisation	45/60	75%	2=
Embodied impacts	45/60	75%	2=

Emissions (CO_2 from production and transport)	42/60	70%	4
Site stewardship and biodiversity	41/60	68%	5
Emissions (excluding CO_2)	38/60	63%	6
Mains water consumption	37/60	62%	7=
Energy efficiency	37/60	62%	7=

Social Issues

The social dimension of sustainability is less well-understood and represented within precast manufacturing, but rather tends to home in on a few serious issues, such as health and safety (for which there are sector and national targets, e.g. Concrete Targets 2015 which is a health and safety scheme for the industry that has "an overall long-term expectation of 'Zero Harm' to all those involved in the industry". The target set is a 50% reduction in Lost Time Injury Frequency Rate (LTIFR) for direct employees and Lost Time Injuries (LTIs) for contractors. Other social issues tend to revolve around the workforce and the local general public/neighbours. Unlike the on-site based construction industry (which has the Considerate Constructors Scheme, CCS, 2011), no overarching scheme exists against which social achievements can be measured in the precast industry, but again we see from Table 7, that approval ratings are generally high, indicating the respondents' support for these issues. Table 7 shows that Health and Safety is clearly ranked first (with an approval rating of 54/60, or 90%), followed byRespect for people at 75%, and Employment and skills at 73%.

Table 7: Weighted scores and ranked list of social aspects.

Social issues management	Weighted score	Percentage 'approval rating'	Rank
Health and safety	54/60	90%	1
Respect for people	45/60	75%	2
Employment and skills	44/60	73%	3
Local communities	43/60	72%	4=
Employee satisfaction	43/60	72%	4=

Economic issues

Respondents were specifically asked questions on productivity, taxes paid, contracts awarded and executed, and how these affect the achievement of sustainability goals within their respective companies. The responses obtained from the Likert-scale question shows that the cost of all goods, material and services was ranked first (with an approval rating of 46/60 or 77%, see Table 8). This was followed by taxes paid at 75%. There was a tie in third place, where penalties and liabilities and annual profits and tax/revenues had 73% each. These results from the respondents under economic issues show high approval ratings, confirming the economic imperative to business.

Table 8: Weighted scores and ranked list of economic aspects.

Economic issues management	Weighted score	Percentage 'approval rating'	Rank
Costs of all goods, materials and services	46/60	77%	1
Taxes paid	45/60	75%	2
Penalties and liabilities	44/60	73%	3
Annual profits after tax/revenues	44/60	73%	3=
Productivity	43/60	72%	5=
Contracts awarded and executed	43/60	72%	5=

So, the outcome from this group of questions about the three 'pillars' of sustainability is that most issues received quite a high approval rating, the minimum was 62% (energy efficiency), perhaps confirming the inclusion of all these aspects within the industry's KPI dataset. With an approval rating of 92%, environmental management systems were seen as an important tool in managing for sustainability (confirming Curkovic and Sroufe's observations, 2011), but concerns around health and safety (90%) were also clearly at the forefront of the respondents' minds.

Understanding change in the precast concrete industry

The next set of questions asked the respondents to consider the nature of the precast industry and its companies in respect of implementing change. There are increasing legal and commercial pressure for the UK construction industry to be more sustainable (Bennett and Crudgington, 2003). Various stakeholders within the construction industry have recognised the need for a major change in the sustainability of the UK construction industry (BERR, 2008; 2009) and the UK precast concrete industry as a major player in the construction industry's commitment to sustainable construction is not immune to this. Holton et al. (2010) investigated the precast concrete industry's management of sustainability issues based on Roome (1998) with regards to "strategic organisational development and change in management structure, systems and competencies". This also provided the background to the questions asked on change management and how the industry is responding to it.

Drivers for change

The respondents were asked to identify one main driver for change within the industry. The results indicate the presence of a range of drivers, from both inside and outside the industry, as shown in Figure 6 – in this instance the number is too small to draw meaningful conclusions about the relative importance of each driver; rather it is the balance/range which is of interest here.

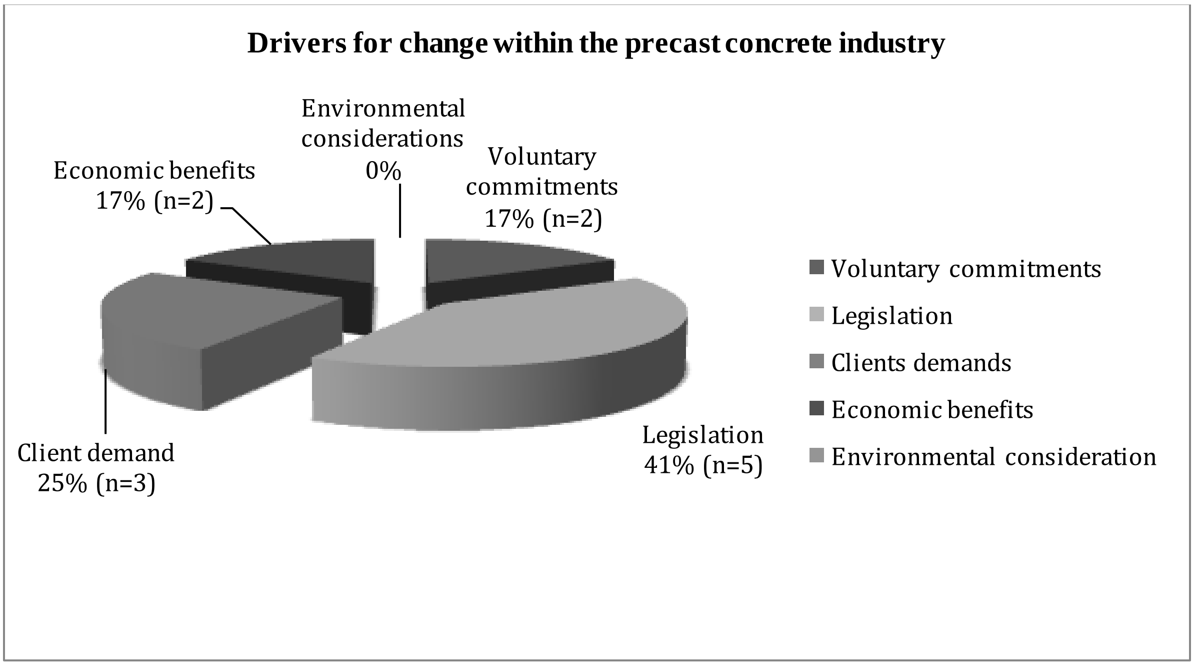

Figure 6: Drivers for change in the precast concrete industry.

Of the twelve companies that responded, five named Legislation as the most effective driver for initiating change and three selected client demand. These are both external drivers, and their influence is strongly supported in literature (Thorpe *et al.* 2008; BERR, 2009). Interestingly, four SMEs chose 'Legislation' – clearly these organisations tend to wait 'until they have to' to instigate change, whereas larger companies may have the resources to 'get ahead of the curve' and act on a voluntary basis. Importantly, the respondents showed that environmental considerations are not sufficient in their own right to drive change, however probing a little further, three respondents said that combinations of drivers were more likely to make change happen (likely to be a combination of economic benefits, client demand and legislation).

Two respondents explained clearly how their businesses had responded to the external (market) drivers, implemented change and so realised benefits for their companies:

> *"The sustainability initiatives of the UK precast concrete industry are largely following wider trends within the market. In particular the increasing need for hard metrics to show a demonstrable understanding and reduction in resource use allied to ethics/ responsible*

product sourcing. We're monitoring better and now doing something with the data in particular; water, waste, electric and fuel usage – it's helping us drive down costs." (Medium sized precast concrete landscaping and building products manufacturer based in East Midlands, UK).

"Our company is aligning its business objectives with stakeholder expectations, which are ever growing. The UK precast concrete industry presents a significant and appropriate stakeholder view. The KPIs for energy, waste, materials use, training, water use, community, and so on, are driving our business processes to make improvements and lessen the environmental impacts of both our products and business." (Large precast concrete block and paving company based in Yorkshire, UK).

Barriers to change

Like the previous question, the respondents were asked to state which barriers they thought held back change in the industry. All twelve responded with five citing cost as the most significant challenge. Suggestions in the other category came from SME businesses who cited: lack of interest, economic climate (cost) and "*lack of legislation and clear direction on policy from government*" (A large precast concrete manufacturer and a construction and building materials supplier). Figure 7 shows the responses to this question.

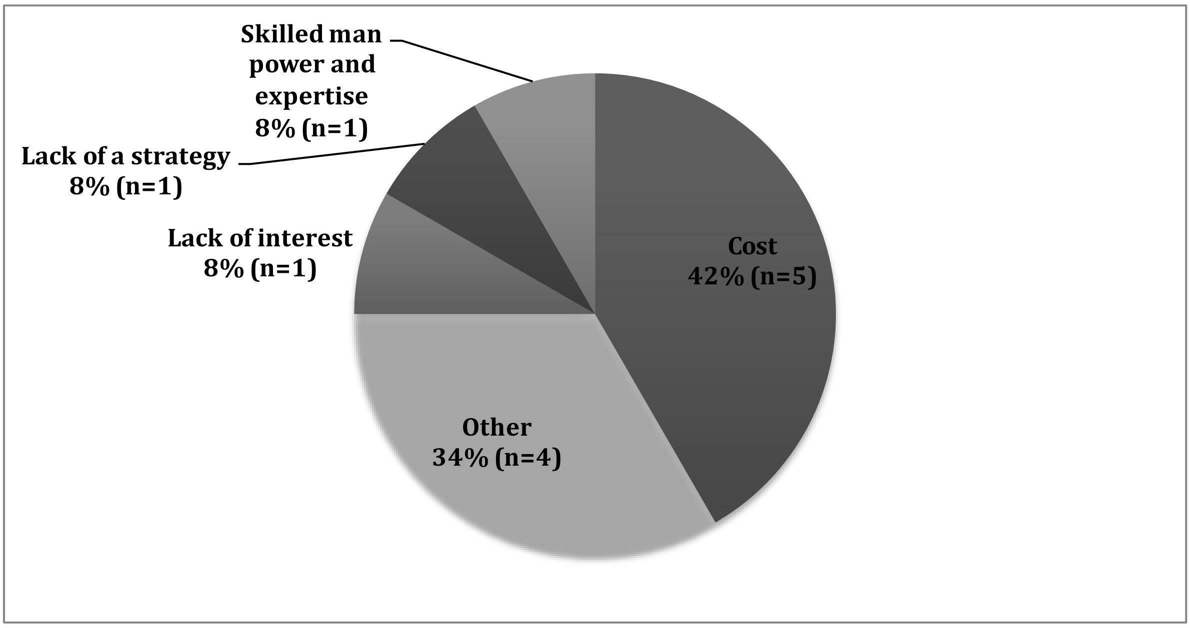

Figure 7: Barriers to change in the precast concrete industry.

These questions were deliberately framed generally and not specifically around PS, because the respondents might not have had sufficient knowledge or experience of PS to be able to give informed answers. While this approach inherently reduces the applicability of the result directly to PS, nevertheless there is evidence of a relationship between the answers to these two questions. It appears that the business case to implement any change in the industry may need to be based on there being a positive potential measured against a range of factors, which would probably include evidence of:

- clear commercial benefits to the business, either increased revenue or reductions in costs, or both;
- demand from the market, via clients/customers;
- demand from the sector, industry or policy-makers; and/or,
- legislation being planned or already in place.

This list concurs with Kleindorfer et al. (2005), Scheer and Rubik (2006) and Seuring and Müller (2008). Seuring and Müller (2008) also discuss risk as a driver for change in this context, but this was not mentioned by the respondents, so does not appear, for the moment at least, to be a relevant driver for precast companies.

Towards an overarching vision for PS in the industry

Finally, the respondents were asked about their understanding of what product stewardship meant, in the context of the precast concrete industry. They were shown models/frameworks from a selection of existing PS schemes from a range of industries and asked to reflect on these, from their own points of view, in an open-ended discursive manner. Their answers suggested that PS, as applied to the precast industry, was essentially grounded within three overarching themes:

- responsible/ethical sourcing of products and materials;
- stakeholder responsibility along the chain of custody of the product and;
- the management of life-cycle impacts .

One respondent (a large company manufacturing concrete blocks, ready mix-concrete and major cement supplier) suggested that the industry should be aiming to be seen as: "*Leaders in innovation, delivering a sustainable built environment and functioning within environmental limits"* which neatly sums up a PS approach and accords well with Figure 3 (although few respondents were able to identify exactly what type of innovation this might be).

Discussion: a tentative understanding of PS in the precast industry

This research set out to achieve three objectives, in the context of the UK precast concrete industry, to:

- define and depict an industry-specific interpretation of PS;
- identify drivers and barriers to implementing a PS scheme; and,
- identify any key components and enabling mechanisms for doing so.

The following discussion will explore these points such that some firm conclusions can be drawn and steps clearly identified should the precast industry develop its own PS scheme in the future.

Overall, the results of this research correspond well with existing literature on PS, as outlined earlier, and the models of PS shown in Figures 3 and 4. It is particularly pertinent that the results also align broadly with a definition of PS put forward by the UK 'Green Guide to Specification' (the most closely related source in literature to the subject under investigation): *"PS is demonstrated by continued engagement with use of the product beyond the factory gate and a commitment to improve its life-cycle performance"* (Anderson *et al.*, 2009, p. 9). However, the precast company respondents went further, by echoing Johnen *et al* (2000) and others, in asserting the inclusion of ethical decision-making in their vision of PS. This is certainly reflective of current industry, sector and client target-setting around responsible sourcing of construction products (e.g. BERR, 2008; 2009; Glass, 2011). According to BRE Global (2009) and Anderson et al (2009, p.9), responsible sourcing (RS) is established through a culture or ethos of supply chain management and Product stewardship. Anderson et al (2009, p.9) explained further by stating aspects which responsible sourcing of materials addresses which include; stakeholder engagement, labour practices and the management of supply chains serving materials sectors upstream of the manufacturer. The UK construction industry target outlined in the strategy for sustainable construction states that 25% of all products used in construction projects must be from a certified responsible sourcing scheme, so this is topical and probably at the forefront of the respondents' minds.

The results can also be discussed in the context of the PS models shown in Figures 3 and 4. Developed from literature, the two models offered a useful insight into the landscape of the PS subject for the interviewees; the models and several industry PS schemes were used helpfully as prompts during the interview process. While the research instrument did not specifically set out to interrogate the models, it is interesting to note that the respondents' feedback did align fairly well with the four conceptual components shown in Figure 3 and they also identified some key structural components under both Impacts assessment and Impacts mitigation, in Figure 4. Hence, there is certainly some value in the two models in helping to depict what is meant by product stewardship in this industry, but a degree of caution should be exercised prior to any further extrapolation or application.

Respondents considered that environmental management systems, waste minimisation, recycling, and life-cycle assessment should be early priorities for a PS scheme (echoing their responses earlier, with approval ratings of 92%, 75%, 77% and 65% respectively), although it is curious that carbon emissions/climate change were not included as this forms such a high-profile dimension to UK government policy currently BERR, (2008; 2009). In addition, no social or economic issues were cited as priorities for a PS approach going forward; even health and safety (which had a 90% approval rating) was not mentioned – perhaps respondents felt that PS was essentially driven by environmental factors) or that health and safety was already mature in the legislation, industry target-setting and/or company approach.

Certainly there is a need to drill down further and expand the sample to better understand what issues might and should be included; evidence of the need for greater breadth came from one respondent, describing his vision for a more sustainable precast industry as:

"...the use of less resource while meeting market demands, legislation, grant, financial incentives, the use of more recycled products, greater research and development in alternative technologies, cement with lesser CO_2, and close working relation with suppliers are amongst the general vision for the industry." (Pipe manufacturer, East Midlands).

The results around stakeholder role and (share of) responsibilities was particularly interesting, with a high degree of asymmetry (see Figure 5). There is substantial opportunity here to explore further the relationship between the various stakeholders in the precast concrete chain-of-custody, but more specifically the dynamic between the designers and the manufacturers (who combined were thought to account for more than 50% of the total impacts of the product. While this question essentially required the respondents to speculate on the relative role of the stakeholders, the presence of design elements in Figure 4 is therefore corroborated by their responses and shows some positive alignment with the works of Fiksel (2009); Hart and Milstein (2003) and others on DfE, Design for environment.

When asked to characterise how a PS scheme for precast might work in practice, respondents debated voluntary or mandatory ownership mechanisms (as shown in Figure 2). In this instance, the respondents believed strongly that, as a starting point, a PS scheme dedicated to the precast concrete industry should be voluntary and be managed by a trade association. There is some evidence from the results that there might also need to be different approaches for large and small businesses, as suggested by Battisti and Perry (2011); respondents from companies with more than 250 employees and higher production capacities appear to have slightly different priorities and may be more agile when it comes to change towards PS.

Conclusions

This research set out to explore the conceptual and structural components of product stewardship within the specific setting of the precast concrete industry, because PS has been identified as a useful framework to mitigate environmental impacts and manage life-cycle impacts of products. As a manufacturing industry, the precast sector faces environmental and other challenges and while it has commenced the collection of KPI data, may benefit from the more structured approach offered by PS. A combination of survey and interview methods were used to characterise the drivers, barriers, mechanisms and implementation potential for a PS scheme for the precast concrete industry. Twelve respondents from a range of companies took part and it became clear that:

- Their understanding of PS, as it might apply to the UK precast sector, aligns well with conceptual and structural models, derived from literature
- Life-cycle management might form the backbone of a PS scheme, together with the use of management systems (such as ISO 14001)
- Manufacturers and designers are thought to be responsible for the lion's share of impacts associated with precast concrete production

- A combination of market and legislative forces might drive PS to become established in the construction products sector
- A voluntary scheme managed by a trade association might be the best starting point.

The results presented in this research paper contribute to the existing knowledge and literature on PS and are novel for this particular sector, but there is a need for additional studies to establish a step-by-step implementation plan that reflects the different needs of large companies and SMEs. There is also scope for further research on the manufacturer-designer dynamic (this would probably be of interest to a wider range of manufacturing sectors and contribute to the literature on DfE). The future role of standards and policy in respect of environmental product declarations are also very pertinent here and may provide a sector-specific driver and framework to encourage the development of product stewardship in the UK construction products sector.

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References

Adams, G. (2010). "10 Principles of Responsible Product Stewardship", available at: http://www.greenbiz.com/blog/2010/07/30/10-principles-responsible-product-stewardship (accessed on 19th October, 2011).

Aliyu, A. A., Glass, J., Clarke, M. A., Elhag, H. K., and Price, A. D. F. (2009). The need for a product stewardship scheme to improve sustainability in the UK precast concrete industry. In: Ketola T. (Ed), *Responsible Leadership*. *Proceedings of the Corporate Responsibility Research (CRR) Conference 2009*, University of Vaasa, Vaasa, Finland, pp. 1-17.

Aliyu, A. A., Glass, J., Clarke, M. A., Elhag, H. K., and Price, A. D. F. (2012). Assessing the potential of Product stewardship for the UK precast concrete industry. In Jones, M.R (Eds): *Proceedings of International Conference Concrete in the Low Carbon Era, University of Dundee,* Scotland, 9 – 11, pp.

Anderson, J., Shiers, D., and Steele, K. (2009), *The Green Guide to Specification: An Environmental Profiling System for Building Materials and Components*, Building Research Establishment, and Oxford Brookes University, HIS BRE Press, Watford, UK.

Armstrong G, Kotler P. (2006). Marketing: an introduction, eighth ed. Financial Times/ Pearson Prentice Hall, Harrow.

Battisti, M., and Perry, M. (2011) Walking the talk? Environmental responsibility from the perspective of small-business owners, *Corporate Social Responsibility and Environmental Management*, 18 (3), 172-185.

Bennett, J., and Crudgington, A. (2003). Sustainable development: recent thinking and practice in the UK. Proceedings of the Institution of Civil Engineers, Engineering Sustainability, 156 ES1 (2003), pp. 27–32.

BERR (2008).Strategy for Sustainable Construction. London: Department for Business, Enterprise and Regulatory Reform, London.

BERR (2009).Strategy for Sustainable Construction - Progress Report.Department for Business, Enterprise and Regulatory Reform, London.

BIBM. (2008). British Precast Concrete Federation. European Precast Book, Galazzano: Bureau International du BétonManufacturé.

Bijen, J.M. (2002). Environmental Information on Concrete, in Dhir, R.K., Dyer, T.D and Halliday, J.E. (Eds.): *Proceedings of International Congress on Challenges of Concrete Construction: Sustainable Concrete Construction,* University of Dundee, Scotland, 5-11 September, pp.57-67.

Brady K, Henson P, Fava J A. (1999). Sustainability, Eco -efficiency, Life-cycle Management , and Business Strategy. Environmental Quality Management. 8; 3, 33-41.

BRE Global.(2009). BRE Environmental and Sustainability (BES) Standard 6001.Framework Standard for Responsible Sourcing of Construction Products. BES 6001: Issue 2.0. Available at: www.greenbooklive.com/filelibrary/BES_6001_Issue_2_Final.pdf.

Bruijn Theo de, (2007).Product stewardship, in Visser, W., Matten, D., and Pohl, M. (Eds.), The A to Z of corporate social responsibility: a complete reference guide to concepts, codes and organisations. John Wiley and Sons, Chichester.

Bryman, A. and Bell , E. (2011). Business Research Methods, Oxford University Press, Oxford.

Carter, C.R.andRogers,D. S. (2008). A framework of sustainable supply chain management: moving toward new theory. International Journal of Physical Distribution & Logistics Management 38 (5), pp. 360 - 387.

Clarke M. A, and Glass, J. (2008). Forget the Concrete: It‘s the added Value that counts. In: Proceedings of the International Conference on Concrete: Construction‘s Sustainable Options, University of Dundee: Dundee, UK, 2008: 1-8.

Concrete Centre. (2008). Concrete Sustainability, [Online] (Updated 13th November, 2008) Available at: http://www.concretecentre.com/main.asp?page=155.

Concrete Targets 2015. (2012) Concrete Targets Health and safety scheme. [Online] (Accessed: 5th January, 2012). Available at: http://www.britishprecast.org/concretetargets/

Considerate Contractors Scheme. (2011) What we do. [Online] (Accessed 13th December, 2011) Available at: http://www.ccscheme.org.uk/

Concrete Society.(2001).Concrete and the environment, Concrete Society 35(8) p.39-46.

Construction Product Association. (2009). The construction products industry. Construction Product Association website, http://www.constprod.org.org.uk; 2009 [accessed on: 21st June, 2009].
Curkovic, S. and Sroufe, R. (2011).Using ISO 14001 to promote a sustainable supply chain strategy, *Business Strategy and the Environment*, 20(2), 71-93.

Department for Environment, Food and Rural Affairs.(2010). Producer responsibility. Available at: http://www.defra.gov.uk/environment/waste/producer/index.htm (accessed on: 19th August, 2010).

European Commission, 2007."The new SME definition User guide and model declaration". Available at: http://ec.europa.eu/enterprise/policies/sme/files/sme_definition/sme_user_guide_en.pdf. (accessed on: 13th June, 2011).

Elhag, H., Glass, J., Gibb, A.G.F., Clarke, M., Budge, c. And Bailey, G.K. (2008).Implementing environmental improvements in a manufacturing context: a structured approach for the precast concrete industry, Int. J. Environmental Technology and Management, 8(4), p.369 - 384.

Elkington, J. (1997). *Cannibals with Forks: The triple bottom line of 21st century business*. Capstone: Oxford.

European Union. (2011). Declaration of performance. [Online] Available at: http://ec.europa.eu/enterprise/sectors/construction/declaration-of-performance/index_en.htm. [Accessed on: 16th December, 2011].

European Union.(2011), "Small and Medium-sized Enterprises (SMEs) Definition". Available at: http://ec.europa.eu/enterprise/policies/sme/facts-figures-analysis/sme-definition/index_en.htm (accessed 19th October, 2011).

Fiksel, J. (2009). Design for Environment; A guide to Sustainable Product Development. McGraw-Hill Professional: New York.

Flower D.J.M and Sanjayan, J. G. (2007). Green House Gas Emissions due to Concrete Manufacture. International Journal of LCA 12(5) pp. 282-288.

Fullanai Palmer. P., Puig, R., Bala, A., Baquero G., Riba J., Raugei M. (2011) From Life Cycle Assessment to Life Cycle Management: A Case Study On Industrial Waste Management Policy Making. Journal of Industrial Ecology. 15(3):458-474.

Haigh, R. (2008). Interviews; A negotiated partnership", Knight, A. and Ruddock, L., Advanced Research Methods in the Built Environment, Wiley- Blackwell, Oxford, p.111-121.

Hart S.L. (1997). Beyond Greening: Strategies for a Sustainable world. Harvard Business Review. Jan. - Feb. 1997, 66-76.

Hickle, G. T. and Stitzhal, D. (2003), Apportioning the responsibilities for product stewardship: A case for a new federal role, Environmental Quality Management, Vol. 12, No. 3, pp.1-16.

Hill M K. (2010). Understanding Environmental Pollution.3rd ed. Cambridge University Press. Cambridge.

Holton I, Glass J, and Price A. (2008). Developing a Successful Sector Sustainability Strategy: Six Lessons from the UK Construction Products Industry. Corporate Social Responsibility and Environmental Management. 15, 29-42.

Holton I., Glass J., Price A. (2010). Managing for sustainability: findings from four company case studies in the UK precast concrete industry. Journal of Cleaner Production.18, 152-160.

Hopwood, B., Mellor, M. and O'Brien, G. (2005), Sustainable development: mapping different approaches. Sustainable Development, 13: 38–52.

Horne, R., Verghese, K. and Grant, T. (2009). Life cycle assessment: principles, practice, and prospects. Csiro Publishing. Collingwood.

ISO 14040:2006. Environmental management. Life cycle assessment. Principles and framework.International Standards Organisation.

Johnen, B. , Foster L, Thomas M. (2000). Stewardship in the Agrochemical Industry. Zeneca Agrochemicals, available online at: http://www.rsc.org/delivery/_ArticleLinking/DisplayArticleForFree.cfm?doi=b006246o&JournalCode=PO (accessed on: 13th July, 2009).

Johnson G, Scholes K, Whittington R,. (2008). Exploring Corporate Strategy. 8th edition. Pearson Education Limited, Harlow.

Jorgensen T. H. (2008). Towards more sustainable management systems: through life cycle management and integration. Journal of Cleaner Production. 16, 1071-1080.

Kleindorfer, P.R., Singhal, K and van Wassenhove, L.N. (2005). Sustainable operations management, . Production and Operations Management, 14 4 (2005), pp. 482–492.

Kreith, F. and Tchobanoglous, G. (2002).Handbook of solid waste management. McGraw - Hill Professional. Second ed. New York; London.

Lewis, H. (2005). Defining product stewardship and sustainability in the Australian packaging industry.Environmental Science and Policy. 8, 1, 45-55.

Lippmann, M. (2009). Environmental Toxicants: Human Exposures and Their Health Effects. John Wiley and Sons, Hoboken, New Jersey.

Lozano, R. (2008). Envisioning sustainability three-dimensionally. Journal of Cleaner Production, 16 17 (2008), pp. 1838–1846.

Lozano, R., and Huisingh, D. (2011) Inter-linking issues and dimensions in sustainability reporting, *Journal of Cleaner Production*, 19, 99-107.

S. Burke, S and Gaughran, W.F. (2006) Robotics and Computer-Integrated Manufacturing 22 , pp. 566–575.

Madu C. N. (2007). Environmental planning and management. Imperial College Press, London.

Nightingale D. E. B and Donnette R. (2002).Product stewardship, in Kreith, F. And Tchobanoglous, G. 2002. Handbook of solid waste management. McGraw-Hill Professional: New York.

Northwest Product Stewardship Council.(2011). Missions and Objectives.Northwest Product Stewardship Council website. Available online at: http://www.productstewardship.net/about.html; [accessed on: 20th October, 2011].

Optimat.(2008). Sustainable Construction Strategy for the UK Concrete Industries.Optimat, East Kilbride.

Product Stewardship Institute. (2011). What is Product stewardship? Product Stewardship Institute website. Available online at: http://www.productstewardship.us/displaycommon.cfm?an=1&subarticlenbr=55; [accessed on: 25th October, 2011].

Product Stewardship Foundation. (2011). What is Product stewardship? Product Stewardship Foundation website. Available online at: http://www.productstewardship.org.nz/component/option,com_frontpage/Itemid,1/. [accessed on: 25th October, 2011].

Rainey, D.L. (2006). Sustainable business development: inventing the future through strategy, innovation, and leadership, Cambridge University Press, New York, NY.

Seuring, S. and Müller, M. (2008).From a literature review to a conceptual framework for sustainable supply chain management. Journal of Cleaner Production, 16, pp. 1699–1710.

Sakai, K. (2008). Sustainability in the concrete sector: CO2 reduction scenarios. Concrete Engineering International, Winter, 2008, p. 8-9.

Sustainable Concrete. (2009). "The Concrete Industry Sustainability Performance Report", available at: http://sustainableconcrete.org.uk/concrete_sustainable_strategy/concrete_sustainable_report.aspx. (Accessed on: 4th October, 2011).

Sustainable Concrete Forum.(2010). The Concrete Industry Sustainability Performance Report; 2008 performance data and release of 2012 performance targets.SCF. London.

Thorpe, D., Ryan, N. and Charles, M. (2008).*Environmental sustainability – a driver for innovation in construction SMEs?* In: 3rd International Conference of the CRC for Construction Innovation: Clients Driving Innovation: Benefiting from Innovation, 12-14 March 2008, Gold Coast, Australia.

United States Environmental Protection Agency. (2010). "What is Product Stewardship?" Available at: http://www.epa.gov/epawaste/partnerships/stewardship/basic.htm#prod; 2010 (accessed on: 24th February, 2010).

APPENDIX D Paper 4

Aliyu, A. A, Glass, J., Clarke, M. A, Elhag, H. K and Price, A.D.F (2012). Exploring EPDs as a mechanism of enhancing Product stewardship in the UK precast concrete industry. Journal for Cleaner Production (In draft).

Exploring EPDS as a mechanism for enhancing product stewardship in the UK precast concrete industry

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Abstract

Environmental Product Declarations (EPDs) is one of the most comprehensive and informative tools to communicate the environmental impact information for different products and services across the supply chain. Due to a range of reasons there has been an increased interest and demand by different stakeholders within the construction products sector for reliable and detailed information on the environmental performance of different products and goods in the industry, including precast concrete products. This has created an incentive for different product sectors to address the issue of EPDs and communication of environmental information using a more comprehensive approach such as product sector reporting, labelling and accreditation schemes.

This paper looks at the potential of an industry approach to the communication and reporting of product stewardship and life cycle management information through the development and operation of a precast concrete sector EPD scheme. The paper further explores how a possible scheme format should look like and assesses the main challenges and factors associated with the implementation of a successful EPD labelling scheme. Following a literature review and a focus group with 10 precast concrete manufacturing companies, a number of factors and challenges associated with the nature of the industry, the political environment, and the supply chain, were identified. In depth interviews were carried out afterwards which helped in examining these challenges and factors further and offered indications on how product stewardship can be affected by the challenges of uncertainty, nature of the industry and European legislation.

The paper then looks at how such EPD labelling scheme can later contribute to a wider holistic approach addressing the overall life-cycle management and stewardship of precast concrete products within the entire sector.

Keywords: Environmental Products Declaration; Product stewardship; responsible sourcing; precast concrete industry

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1. Introduction

Environment Product Declaration (EPDS) have been developed by different organisations and countries like; UK, Sweden, France, Norway, Germany, Italy, US, Switzerland, Australia among other countries (Ingwersen and Stevenson, 2012 p.202; Envirodec; 2012, Manzini *et al.* 2006 p. 126, Anderson and Thornback, 2012 p.2). Product manufactures are aware about stakeholders increasing demands and pressure regarding the need to declare, communicate and transmit the environmental credentials and information of products and services. Pressure on companies comes from new regulations and new requirements (Fet and Skaar (2009 p. 201). According to (Manzini *et al.* 2006 p. 118), one of the most effective and innovative ways to achieve this is through the use of EPD. The UK precast concrete industry is continuously and actively pursuing ways and means to improve the sustainability of its products (Holton *et al.*, 2008, 2010; Aliyu *et al.*, 2009). In the view of Erlandsson and Tillman (2009, p.800) relevant, comprehensible and verifiable information are required and necessary in any attempt to mitigate the environmental impacts of a product from production, manufacture and consumption. Fet and Skaar (2009 p. 201) however, opined that the entire lifecycle of a product must be examined for a sufficient understanding of the environmental impacts of a product, that is from raw material extraction, production, use stage, recycling and end of life.

As a specific means of communicating principally environmental information through the life-cycle lens, environmental products declarations (EPD) have an established presence within a range of product manufacturing paradigms across Europe and are of direct relevance to the precast concrete industry, because the wider UK construction products industry is starting to adopt this approach (principally in response to there being points for so doing in schemes like BREEAM).

EPD have been developed by different organisations and countries like the UK, Sweden, France, Norway, Germany, Italy, US, Switzerland and Australia among other countries (Anderson and Thornback, 2012; Envirodec, 2012; Ingwersen and Stevenson, 2012; Manzini *et al.*, 2006). Product manufacturers are aware of stakeholders' increasing demands and pressure regarding the need to declare, communicate and transmit the environmental credentials and information of products and services. Pressure on companies comes from new regulations and new requirements (Fet *et al.* 2009). According to Manzini *et al.* (2006), one of the most effective and innovative ways to achieve this is through the use of EPD. The key objective of which is the systematic communication of environmental information of a product, good and service that is reliable and accurate such that it encourages the need and supply of products and service with less environmental stress. According to Skaar *et al.* (2011), the primary purpose of EPD is to:

> *"enable comparisons between products or services fulfilling identical functions. The comparisons are based on life cycle assessments (LCA) performed of the products and services according to a set of Product Category Rules (PCR) and the ISO14040series".*

ISO14025 (2010) states that an environmental declaration is a claim which indicates the environmental aspect of a product or service which consists of quantified environmental data using pre-set parameters which are based on ISO 14040 and/or including, where necessary, any additional quantitative and qualitative information. EPDs are increasingly being considered by organisations to transmit vital environmental information about the quality of their products and services (Manzini*et al.,* 2006). They provide companies with a cradle-to-grave approach that facilitates product stewardship throughout the value chain of the product (Kylakorpi *et al.*). This can be attributed to the need for more credible, comparable, reliable and verified information by concerned supply chain stakeholders within and in some cases outside the supply chain (Erlandsson and Tillman, 2009; Fava *et al.,* 2011; Ingwersen and Stevenson, 2012). These stakeholders can vary from upstream and downstream along the supply chain. Different countries, organisations, companies and industries have developed or are developing EPD, as shown in Table 18.

Table 1: Comparison of environmental product declaration (EPD) of selected countries

Country	Standardisation body	Programme name	Founded by	Year	Developed areas of PCRs
France	Energy management (ADEME) and the French Standardisation body - Association Francaise de Normalisation (AFNOR)	Display of environmental characteristics of consumer products	National legislation (*le Grenelle de l'Environnement*)	2010	Food, Cleaning products, Personal products, Clothing, Furniture, Cookware, Office products.
Sweden	International EPD Consortium	International EPD system	Swedish Environmental Ministry	-	Agriculture, Forestry and fishery products, Ores and minerals, Energy and water, Food and beverages, Textile and furniture, Wood and paper, Rubber, Plastics, Glass and Chemicals, Metals, Machinery and appliances, Transport equipment and services, Services, Construction goods and services
Japan	Japan Environmental Management Association for Industry (JEMAI)	Ecoleaf and Carbon Footprint of Products	Japan Ministry of Economy, Trade and Industry (MEIT)	2002	Electronics, Office Machines, Utilities, Durable home goods and services

Sources: Climatedec (2012); Ingwersen and Stevenson (2012); JEMAI (2012).

From a critical perspective, Glass (2012) explains that EPD "do not cover the three pillars of sustainability and so on their own do not constitute a fulsome sustainability assessment of a construction product". Steen *et al.* (2008) are of the opinion that EPDs are difficult to understand for professional purchasers and sales people. Some environmental claims can be falsely made without the agreed set-down rules which help to show transparency and provide correct measurement and reporting (Ingwersen and Stevenson, 2012).

The comparison of similar products and the communication of the results gave rise to the development of EPD based on conducted LCA according to ISO14025:2010. Life-cycle Assessments (LCAs) and Life-cycle Inventories (LCIs) were developed and used to show the hot spots and cold spots in the entire product's life cycle. An EPD are therefore developed according to ISO14025:2010. Based on this, BS EN 15804 (2012) describes the different approaches to EPD with respect to the life-cycle stages and building assessment information. These are: cradle-to-gate (declared unit), cradle-to-gate with option (declared unit/ functional unit) and cradle-to-grave (functional unit).

While there are evolving debates within the standards landscape, EPDs are gaining ground as a mechanism to consistently collect and present environmental data, so are of relevance to the management of sustainability within the industry. At present, no construction product industries possess a sector-wide understanding or agreed approach on EPDs in accordance with the new industry standard BS EN 15804 (2012), so there is scope to explore this in the precast industry.

2. Methodology

The aim of this article is to provide and showcase a conceptual framework for an precast concrete industry EPD and to analyse the implementation procedure of how the EPD will work and how it will be set up. Key issues in regards to the complexity, size and production capacity of the Small and Medium Enterprise (SME) companies within the industry are also discussed.

The methodology used to carry out this research was based on action research through conducting a literature review, a focus group and in-depth semi structured interviews. Action research is an 'approach to research which aims at both taking an action and creating knowledge or theory about that action' (Coghlan and Brannick, 2010, p. ix). In the words of Shani and Pasmore (1985, p. 439):

"Action research may be defined as an emergent inquiry process in which applied behavioural science knowledge is integrated with existing organisational knowledge and applied to solve real organisational problems. It is simultaneously concerned with bringing about change in organisations, in developing self-help competencies in organisational members and adding scientific knowledge. Finally, it is an evolving process that is undertaken in a spirit of collaboration and co-inquiry".

(Jesson *et.al.* 2011) provides the following definition: "A literature review is a library or desk-based method involving the secondary analysis of explicit knowledge, so abstract concepts of explicit and tacit knowledge are explored". According to (Fink, 1998); "*A Literature review is a systematic, explicit, and reproducible design for identifying, evaluating, and interpreting the existing body of recorded documents"*. Meridith (1993) explains that the aim of literature review can be classed into two objectives: first, is to summarise present or active research within the area through the identification of patterns, issues and themes. Secondly, is the identification of the conceptual content within the field.

The state of the art literature review was drawn from year 2000 – 2011 from different literature sources which include; I e.t.c. The review focused on the existing literature on EPD, EPD work in the construction industry and lessons from other EPD works carried out in other industries that can be of benefit to the precast concrete industry. The review was carried out to consider how the precast concrete industry can rise to the growing and increasing demand for credible, reliable and verifiable environmental information of products and services by various stakeholders within and outside the supply chain.

3. Definition of EPD

According to ISO14025 (2010 p. 2), an environmental declaration is a claim which indicates the environmental aspect of a product or service which consist of quantified environmental data using preset parameters which are based on ISO 14040 and/ or including where necessary any additional quantitative and qualitative information.

EPDs are increasingly being considered by organisations to transmit vital environmental information about the quality of their products and services (Manzini *et al*, 2006 p, 118). EPD provide companies with a cradle-to grave approach that enables product stewardship all through the product's value chain. (Kylakorpi *et al.,* 2007). This can be attributed to the need for more credible, comparable, reliable and verified information by concerned supply chain stakeholders within and in some case outside the supply chain (Ingwersen and Stevenson, 2012 p. 102; Fava *et al.*, 2011 p. 9; Erlandsson and Tillman, 2009, p. 800). These stakeholders can vary from upstream and downstream the supply chain. Different countries, organisations, companies and industries have developed or are developing EPD. The life cycle (i.e design, production, use and end-of-life) of products and services constitute environmental footprints, energy use and atmospheric pollution. Over the last two decades there have been an increasing number of companies that compile environmental information to address these issues from a life cycle perspective. The comparison of similar products and the communication of the results gave rise to the development of EPD based on conducted LCA according to ISO 14025. Life cycle assessments (LCAs) and Life cycle inventories (LCIs) were developed and used to show the hot spots and cold spots in the entire product's life cycle. EPDs are developed according to ISO14025:2010.

From a critical perspective, Glass (2012) explains that EPDs "do not cover the three pillars of sustainability and so on their own do not constitute a fulsome sustainability assessment of a construction product". (Steen *et.al.,* 2008 p.589) opinions that EPDs are difficult to understand for professional purchasers and sales people. Some environmental claims can be falsely made without the agreed set down rules which help to show transparency and provide correct measurement and reporting (Ingwersen and Stevenson, 2012 p. 107).

From a broader perspective, the objectives of EPDS far outweigh its challenges. These objectives are numerous however, as stated in ISO(2001 p.1):

"the overall goal of environmental labels and declarations is, through communication of verifiable and accurate information that is not misleading, on environmental aspects of products and services, to encourage the demand for and supply of those products and services that cause less stress on the environment, thereby stimulating the potential for market-driven continuous environmental improvement".

This implies that the key objective of EPD is the systematic communication of environmental information of a product, good and service that is reliable and accurate such that it encourages the need and supply of products and service with less environmental stress. EPDs provide vital information regarding the environmental credentials and performances of a product or service.

According to Skaar and Fet (2011) the primary purpose of EPD is to "*enable comparisons between products or services fulfilling identical functions. The comparisons are based on life cycle assessments (LCA) performed of the products and services according to a set of Product Category Rules (PCR) and the ISO14040 series*".

4. EPD and the UK precast concrete industry

Currently in the UK, the British Research Establishment (BRE) EPD scheme which is based on the Environmental profiles and Green Guide ratings is being used to make comparison and to demonstrate the environmental performance of different construction products from a life cycle perspective.

Fet *et al.,* (2009 p, 202) suggest there is a potential to create EPD specifically for the construction materials without carrying out a Life cycle assessment (LCA), however, this should be made clear that the EPD covers environmental impacts from raw material extraction to production. According to ISO (2007 p.6), "Where appropriate and justified, the environmental impact of the building product may be given for any part of the life cycle, [e.g. only the production stage, "*cradle to gate*" or as a "*cradle to gate with option*, In this case, the EPD is not based on a LCA but on one or more information modules". Further to this, based on the ISO 21930, it must be clearly stated that the EPD only consists of certain life cycle stages and hence will becomes an information module which can be expresses per declared unit. But for the complete life cycle stages the EPD is called "cradle to grave" which is based on LCA expressed per functional unit. Appendix B shows all the mandatory and optional elements and information modules in declared units and functional units.

Zakarrisson *et.al.,* (2008) named a five step approach to EPD development, which includes:

f. Making a simplified or streamlined life cycle assessment, LCA, to identify the most significant environmental aspects and impacts of the product;
g. Formulation of Product Category Rules together with interested parties;
h. Making a detailed life cycle assessment to validate and supplement the results of the initial assessment;
i. Drafting of EPD; and
j. Independent verification of the life cycle assessment and the EPD.

ISO 14025 clearly specifies the two methodologies to be followed for the development of Type III environmental declarations. Figure 2 shows option A and option B. Both of the options require; LCA study, which includes; goal and scope definition, inventory analysis (LCI), interpretation. The major difference between the two options is option A requires impact assessment (LCIA) while, option B requires none.

For the UK precast concrete industry, the opportunities provided by EPD development are quite enormous. As shown in figure 3, the natural starting point of EPD development is the mandatory requirement for a product category (PC) to be developed for each of the products within the industry. The next step is to collect and/ or produce appropriate LCA based ISO14044. A functional unit will be identified as the basis for social unit measurement (e.g m^3 for concrete slabs, roofing tiles e.t.c) and a basis to which direct comparison of similar or different products could be made. The EPD can be owned and managed by manufacturing companies or their trade federation (BPCF), while the PCR can be owned by an independent third party in accordance to international standards (ISO14025). Validation and registration is required after this process.

5. Developing a precast-specific scheme

The UK precast concrete industry has an opportunity to develop an industry-wide approach to EPD that is compliant with all the relevant ISO and BS standards (e.g. ISO 14025, BS 15804, ISO 14044, CEN 350 etc.) related to EPD. The EPD scheme can be centralised and managed by the trade federation with third-party independent verifiers as PCR consultants. This will go a long way in positioning the industry to voluntarily market its products and green credentials in a more efficient and effective manner while also reducing its environmental footprints/impacts without the enforcement of an impending European Union (EU) legislation in 2013. No other sector has yet taken such a leadership position using EPD. In practice, the natural starting point of EPD development is the mandatory requirement for a product category (PC) to be developed for each of the products within the industry. The next step is to collect and/or produce appropriate LCA-based ISO14044. A functional unit will be identified as the basis for unit usability measurement (e.g. m^2 for concrete slabs, roofing tiles, etc.) and as a basis on which direct comparison of similar or different products could be made (identified as 'Functional Equivalence'). The EPD can be owned and managed by manufacturing companies or their trade federations (e.g. BPCF), while the PCR can be owned by an independent third party in accordance with international standards (e.g. ISO14025, BS EN 15804). Validation and registration is required after this process.

6. Structure and functional process

The EPD framework developed will guide the industry towards setting up a dedicated precast concrete EPD scheme. The proposed scheme will vary from one product manufacturer to another. The five key stages of the EPD scheme are as follows.

Stage A – Manufacturer registration and training workshop
Stage B – The use of product category calculator, and the production of unverified EPD from data that was collected and inputted into calculator.
Stage C – EPD verification
Stage D – EPD certification
Stage E – Release of EPD

These are presented in detail below and shown in Table 4.8 and Figure 4.11.

Stage A includes various stakeholder are involved in stage A which includes; BPCF, precast concrete, member companies involves setting up an EPD steering group or committee. BPCF member companies will then decide on committee composition and their term of reference. The steering group or committee is responsible in appointing qualified and competent consultants that will develop a product category document.

Stage B includes three important phases of product category document development. The first phase is defining the product category according to ISO 14025, second stage includes collection or production of LCA data and the third and final stage is the determination of product category rules by specifying all shared goals and rules for product category LCA and writing of instructions on how to produce captured data for declaration. The main stakeholders in this stage are the consultants.

Stage C comprises establishing an EPD Training course, verification of the course by a consultant and approval by the steering group or committee**.** The main stakeholders involved in this stage are the consultants and the steering group or committee.

Stage D basically includes the appointment of a programme operator. The programme operator establishes the general EPD programme requirements, workshops, launching of the scheme and issuance of certificates.

Stage E is the final stage of the framework and involves the certification and accreditation of the EPD scheme. The key stakeholder involved include; the certifiers e.g. United Kingdom Accreditation Service (UKAS) or International EPD system.

How the precast concrete industry EPD scheme will be set up

The framework provided below outlines the key steps needed to develop an EPD scheme for the UK precast concrete industry into divided work packages or stages.

Stages	Preparation	EPD work stages				Stakeholders responsible	Stakeholder responsibility
		Steps	Category		Task description		
Stage A	BPCF member companies nominated representatives meet to decide on steering group or committee and team composition. Committee to decide or choose qualified and competent consultants for PCR document if necessary	Set up an EPD steering committee	A1		BPCF member companies nominated representatives meet to decide on steering group and team composition, committee mandate, terms of reference and operation and general running of committee		Steering Group or committee will oversee the general operation, development, and implementation and running of an effective and efficient EPD scheme for the UK precast concrete industry.
Stage B	Establish Product Category Rules (PCR) and PCR document	PCR should be developed according to ISO 14025 section 6.7	B1		Define product category; identification and classification of specific product or group of products that can fulfil specific functions		LCA based data for materials, parts and other inputs (as carried out based on B1 below) are the information modules and may represent the whole or a portion of the life cycle of those materials or parts.
				B1.1	Generate PCR document		PCR document should be in conformity with
				B1.2	Verification of PCR document		Independent verification body or consultants contacted by the programme operator must ensure that the verification procedure for review and independent verification are in conformity with ISO 14025 section 8 and BS EN 15804.
			B2		Collect or produce LCA Bank (Generic) e.g Ecoinvent, GABi database, INIES, European LCA data base e.t.c.		-
				B2.1	Establish LCA data bank or repository		LCA should be conducted by the relevant stakeholder (LCA researcher, Manager, consultant etc.). In the event were LCA are available and applicable, delegated or assigned stakeholder manages the LCA data
				B2.2	Verify data within LCA data bank according to BS EN 15942 by an independent third party		
	Collect and / or produce appropriate LCA	LCA development or accessing LCA data bank for PCR document use	B3		Develop or produce LCA calculator		-
			B4		Verification of the LCA calculator		
			B5		Approve PCR document/ calculator and establish EPD format and content		Responsible stakeholder ensures that the PCR document produced is in conformity with ISO 14025 section 6.7
Stage C	Course approval, verification and establishing	-	C1		Approval of verifiers and experts, technical support and trainers of product manufacturers		-
				C1.1	Develop syllabus or course contents for training		-
				C1.2	Approve course contents, vetting and revisions		
				C1.3	Invitation of possible scheme verifiers		
				C1.4	Training and workshops		
			C2		Establish list of approved trainers		-
			C3		Verifiers to sign data protection charter		
Stage D	Programme operator assignment	-	D1		Appointment of EPD programme operator		Programme operator to carry out as the relevant tasks and responsibilities as outlined in section 6.3 of ISO 14025 and any other associated standards.
	-		D2		Establish general EPD programme requirements		This should be carried out by the relevant assigned individual(s) or consultant in accordance to section 6.4 of ISO 14025.
			D3		Workshop to approve EPD programme by interested parties		-
			D4		Launch EPD scheme/ programme and issuance of certificates		-
Stage E	Certification and accreditation of EPD	-	**E1**		**Certification by the scheme operator Council and later Accreditation by UKAS/ EPD®.**		**The independent consultant and the appointed verifier will be responsible for this task.**

Glossary of terms

EPD steering committee – is a committee that will oversee the general operation, development, and implementation and running of an effective and efficient EPD scheme for the UK precast concrete industry.
Programme operator – According to ISO 14025, a programme operator is a "body or bodies that conduct a Type III environmental declaration programme. A programme operator can be a company or a group of companies, industrial sector or trade association, public authorities or agencies, or an independent scientific body or other organization". ISO, (2010).

Verifier – an expert or organisation appointed by the programme operator to check the authenticity of LCA data used for the EPD development

Certifier – a recognised independent body that can declare and prove that the EPD developed is fully certified

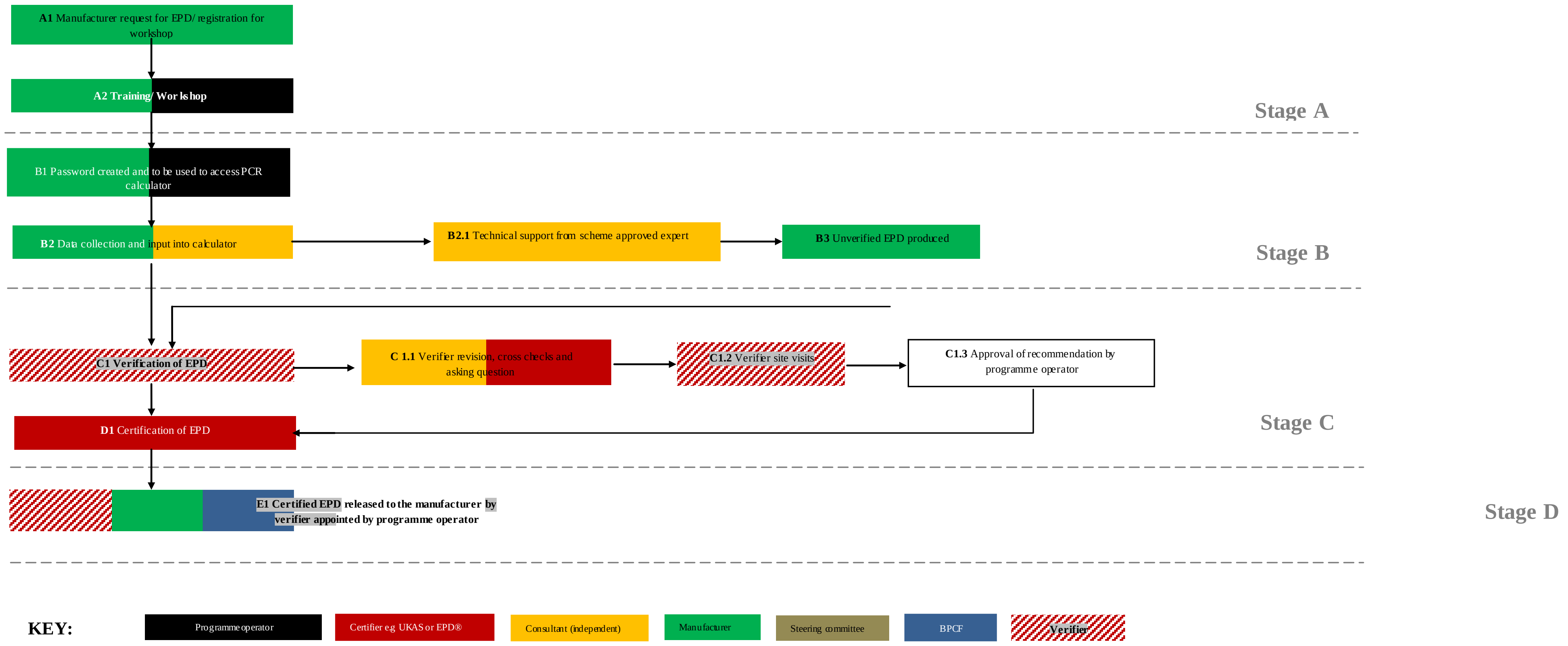
Manufacturer – Precast concrete product(s) manufacturer

Independent consultant – appointed individual (s) or organisation**:**

KEY:							
	Programme operator	Certifier e.g UKAS or EPD® e.t.c	Consultant (independent)	Manufacturer	Steering committee	BPCF	Verifier

How the precast concrete industry EPD scheme will work

This diagram describes the main steps to be taken under the proposed scheme to develop and verify a manufacturer product EPD. The EPD work stages may vary from one product manufacturer to another.



7. EPD framework implementation scenarios

The structure and process of the proposed EPD scheme have been shown in the preceding figures, but in order to understand the practical implementation of the scheme, a focus group and interviews were used. This section provides an outline of the possible step-by-step implementation of the EPD through four scenarios based on data from selected companies within the UK precast concrete industry, but with additional illustrative descriptions to help portray the key factors that might influence the process. International standards ISO 14001, ISO 14024, ISO 14025 and BS EN 15804 are assumed to be used as the platform for the implementation. Factual information about the size, production capacity and profile of four real precast concrete companies was used in making generic assumptions regarding the implementation, as shown Table 2. It is clear from the accounts that company size, breadth of product range, complexity in the raw materials supply-chain and levels of sustainability competence/investment within the business are all relevant to the ease with which an EPD might be developed.

Table 2: Profile of selected precast companies

Companies	No. of employees	No. of sites	Production (t)	Types of product
Company A	200	500	1,300,000	Ready mix, aggregates, precast and cement
Company B	1,500	10	2,000,000	Landscaping products
Company C	200	No data	500,000	Autoclaved aerated concrete blocks
Company D	60	2	26,000	Structural and architectural precast

Company A

Company A is a multinational company that produces cement and is a major supplier of a range of aggregate, cement, concrete and precast concrete products. The company is the process of implementing PAS 2050 and considering evaluating some form of LCA is selected products. The company has management systems in place (ISO14001, ISO 9001) and BES 6001 for responsible sourcing. As a starting point, after conducting LCA and the collection of LCA data, a PCR document will be created. This information will be feed into a calculator. Company A could choose to go for a cradle to gate approach or cradle to cradle. A functional unit (which is appropriate) would then be selected and used for the product. The EPD document that will be produced would include information about the company, the part of life cycle included and other important information. The company would face challenges in data collection, owing to its size and scale of operations, as well as its product range. It would need to have a clear strategy at corporate level to ensure that the quality of data collection remained consistent across the business. Company A would face a significant cost to undertake this exercise, but when completed it would have a unique position in the marketplace and a powerful marketing message around its comprehensive approach to life-cycle management. Hence, the chance to be an 'early adopter' might be sufficiently convincing to undertake this major programme of EPD development and its established management systems provide evidence that the company is willing to invest in mechanisms which demonstrate its credentials externally..

Company B

Company B predominantly produces landscape products. The company has key management systems in place, its own carbon calculator and an award-winning customer-facing website on sustainability. The company needs to conduct LCA or use LCA data with BRE. If the company choose cradle to gate option, then Life cycle inventory information and PCR will be used to create an EPD for the selected products. A functional unit of $1m^3$ will also be used and the EPD document created will include information about the company, the part of life cycle included and other important information. Company B has much fewer sites and a more limited product range compared to Company A, so would clearly face a simpler task in developing EPDs for its product range. The availability of carbon data would be advantageous, provided it is compliant with the PCR and BS EN 15804. In some instances, the assumptions and scope of data collected in legacy life-cycle assessments may not be applicable, so Company B would need to check its data carefully. Company B would also be able to enhance its already successful website with EPD information.

Company C

Company C produces aircrete products. The company has achieved accreditation of its Integrated Management System (IMS) to PAS99:2006 which also include; ISO14001: 2004, OHSAS 18001: 2007 and ISO 9001: 2008. The company is also certified to BRE's Responsible Sourcing of Construction products standards (BES 6001: 2008). Company C also has an energy management system in place. The company could start with an LCA studies, as in the case of Company B and could opt for cradle to gate option, then Life cycle inventory information and PCR will be used to create an EPD for the selected products. A functional unit of $1m^3$ will also be used and the EPD document produced will include information about the company, the part of life cycle included and other important information. Most of the products manufactured by company C have similar content and ingredients composition with 80% of the material used for the Autoclaved aerated concrete coming from Pulverised Fuel Ash (PFA). Inherent impacts e.g. embodied energy from coal fired stations will certainly increase Autoclaved aerated concrete blocks environmental impacts. Other areas that could increase these impacts include the steaming process from autoclaves that is being used for curing.

Company D

Company D produces structural and architectural precast. Company D has certification for ISO 14001, BES 6001 and ISO 9001, the company has two production sites and over 80% of the company's products come from secondary sources. Company D has a potential of addressing the high cement content for its architectural precast concrete products through the use of cement replacement materials. Company D unlike all the other three companies A, B and C will have a much simpler and easier EPD development and implementation due to the number of sites the company owns. Company D could start with conducting LCA studies for its products or use BRE's LCA data, after which a PCR document will then be created. This information will be fed into a calculator. Company A could choose to go for a cradle to gate approach or cradle to cradle. A functional unit of $1m^3$ would then be used for the product. The EPD document that will be produced would include information about the company, the part of life cycle included and other important information.

8. Summary

As part of an overarching PS initiative or scheme for the precast concrete industry, EPD development can offer a realistic and achievable starting point for the mitigation of key environmental impacts. The central contention of this chapter is that EPD can provide reliable, verifiable and accurate information concerning the environmental performance and credentials of precast concrete products. Various examples of wide usage of EPD in different countries and industries point to the fact that their developments help manufacturers, users and other stakeholder towards more transparent disclosure of environmental information of products and services. The UK precast concrete industry has an opportunity to develop an industry-wide EPD that is centralised and managed by the trade federation with third-party independent verifiers as PCR management consultants. This will go a long way in positioning the industry to voluntarily market its green credentials in a more efficient and effective manner while also reducing its environmental footprints/impacts without the enforcement of an impending European Union legislation. Nonetheless, as mentioned previously in respect of implementation of any PS initiative, an EPD needs to be delivered at company level, so while the sector-level bodies within the precast industry can be instrumental, it will be a matter for the individual member companies to invest in their own product EPDs. In this case, the barriers identified within Section 4.5 will be material and so the sector-level bodies may need to investigate further how such barriers might best be overcome to convince their members to act.

9. Conclusion and Recommendation

This paper explores the potential of an industry approach to the communication and reporting of PS and life-cycle management information through the development and operation of a precast concrete sector EPD scheme. It further explores what a possible scheme format should look like, and assesses the main challenges and factors associated with the implementation of a successful EPD labelling scheme. An EPD framework for the industry is also included.

As part of an overarching product stewardship initiative or scheme for the precast concrete industry, EPD development can offer a realistic and achievable starting point for the mitigation of key environmental impacts. The central contention of this paper is that EPD can provide a reliable, verifiable and accurate information of the environmental performance and credentials of precast concrete products. Various examples of wide usage of EPD in different countries and industries point to the fact that their developments help manufacturers, users and other stakeholders towards more transparent disclosure of environmental information of products and services.

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References

Anderson, J. and Thornback, J. 2012. A Guide to Understanding the Embodied Impacts of Construction Products. Construction Products Association. ISBN 978-0-9567726-6-4.

Aliyu, A. A., Glass, J., Clarke, M. A., Elhag, H. K. and Price, A. D. F. (2009). The need for a product stewardship scheme to improve sustainability in the UK precast concrete industry. In: Ketola T. (Ed), *Responsible Leadership*. *Proceedings of the Corporate Responsibility Research (CRR) Conference 2009*, University of Vaasa, Vaasa, Finland, pp. 1-17.

BRE. (2012). Construction Products and CEN TC 350 Standards [Online] Available at: http://www.bre.co.uk/page.jsp?id=2747. Accessed on: 17th April, 2012.

BS EN 15804. (2012). Sustainability of construction works. Environmental product declarations. Core rules for the product category of construction products. London: British Standard Institution.

Coghlan, D. and Brannick, T. (2010). Doing Action Research in Your Own Organization. SAGE Publications Ltd. ISBN 1848602162, 9781848602168.

Climatedec. (2012). International EPD (R) System. [Online] Available at: http://www.climatedec.com/about/Backgound/The-International-EPDRsystem/ Accessed: 10th February, 2012.

DG Environment. (2002). Evaluation of Environmental Product Declaration Schemes, final report.

Erlandsson, J. and Tillman, A-M. (2009). Analysing influencing factors of corporate environmental information collection, management and communication. *Journal of Cleaner Production*, Vol. 17, pp. 800–810.

Envirodec. (2012). EPD® system – a programme for type III environmental declarations with an international applicability. Also known as the Swedish EPD-system. [Online] Available at: www.environdec.com . Assessed on: 11th February, 2012.

Fava, J., Baer, S. and Cooper, J. (2011). Green(er) product standard trends in North America. *Journal of Industrial Ecology,* Vol.15, pp. 9-12.

Fet, A.M., Skaar, C. and Michelsen, O. (2009). Product category rules and environmental product declarations as tools to promote sustainable products: experiences from a case study of furniture production. *Clean Technology and Environmental Policy*, Vol. 11, pp. 201–207.

Fink, A. (1998). Conducting research literature reviews: from paper to internet. Thousand Oaks: Sage; 1998.

Glass, J. (2012) *Extending the concept and validity of responsible sourcing certification through environmental products declaration*. 1st International Conference on Building Sustainability Assessment 2012, 23 – 25 May, 2012, Porto, Portugal.

Holton, I., Glass, J. and Price, A. (2008). Developing a Successful Sector Sustainability Strategy: Six Lessons from the UK Construction Products Industry. *Corporate Social Responsibility and Environmental Management*. 15, 29-42.

Holton, I., Glass, J., Price A. (2010). Managing for sustainability: findings from four company case studies in the UK precast concrete industry. *Journal of Cleaner Production*. 18, 152-160.

Jesson, J., Matheson, L.,and Lacey, F.M. (2011). Doing Your Literature Review: Traditional and Systematic Techniques. London: Sage; ISBN 1848601530.

JEMAI. (2012). Eco-Leaf; Environmental Declaration. [Online] Available at: http://www.jemai.or.jp/english/ecoleaf/pdf/ecoleaf_e.pdf. Accessed: 10th February, 2012.

Kylakorpi, L., Bodlund, B. and Setterwall, C. (2007). LCA – A basis for environmental stewardship in the power industry, The Society of Environmental Toxicology and Chemistry.

Manzini, R., Giuliano N., Massimiliano O. and Emanuele P. (2006). Assessing Environmental Product Declaration Opportunities: a Reference Framework. *Business Strategy and Development* 15 (2) pp. 118–134.

Meredith, J. (1993). Theory building through conceptual methods.International *Journal of Operations & Production Management*, Vol.13 (5) (1993), pp. 3–11.

National Floor Trends (2012). **Using EPDs for Better Transparency. [Online] Available at:** http://www.ntlfloortrends.com/NFT/Home/Images/nft_0112_EPD_img2.jpg. Accessed: 17th January, 2012.

Ingwersena, W.W and Martha J. Stevenson, M.J.(2012). Can we compare the environmental performance of this product to that one? An update on the development of product category rules and future challenges toward alignment. *Journal of Cleaner Production*.Vol.24,pp. 102–108.

ISO. (1999). 14021: Environmental labels and declarations - Self-declared environmental claims (Type II environmental labelling). International Standards Organisation.

ISO. (1999). 14024: Environmental labels and declarations - Type I environmental labelling - Principles and procedures. International Standards Organisation.

ISO. (2001). ISO 14020: Environmental labels and declarations - General principles. International Standards Organisation.

ISO. (2006). ISO 14025:2010. Environmental labels and declarations. Type III environmental declarations. Principles and procedures. International Standards Organisation.

ISO.(2007). ISO 21930: Sustainability in building construction — Environmental declaration of building products. International Standards Organisation.

ISO. (2010). ISO 14025:2010. Environmental labels and declarations. Type III environmental declarations. Principles and procedures. International Standards Organisation.

Schenck, R. (2009). The Outlook and Opportunity for Type III Environmental Product Declarations in the United States of America. [Online] Available at: Institute for Environmental Research and Education; http://lcacenter.org/pdf/Outlook-for-Type-III-Ecolabels-in-the-USA.pdf . Accessed on: 11th February, 2012.

Skaar, C. and Fet, A. M. (2011). Accountability in the Value Chain: From Environmental Product Declaration (EPD) to CSR Product Declaration. *Corporate Social Responsibility and Environmental Management*. 10.1002/csr.275.

Steen, B., Ga¨rling, A., Imrell, A-M, Sanne, K. (2008). Development of interpretation keys for environmental product declarations. *Journal of Cleaner Production*. Vol. 16, pp. 598-604.

Zackrissona, M., Rochab, C., Christiansenc, K. and Jarnehammar, A. (2008). Stepwise environmental product declarations: ten SME case studies. *Journal of Cleaner Production*. Vol.16, (17), pp. 1872–1886.

APPENDIX E

Precast concrete industry Interview and questionnaire programme

Interview and questionnaire programme

Improving sustainability through product stewardship in the UK precast concrete industry:
Information for participants

About the interview and questionnaire programme
This interview study forms part of a joint collaborative Engineering Doctorate research project exploring the potential for product stewardship in the UK precast concrete industry. The project is jointly administered by British Precast Concrete Federation (BPCF) and the Centre for Innovative and Collaborative Engineering (CICE), Loughborough University.

1. Introduction and background

1.1 What is Product stewardship?

Product stewardship provides systematic approaches and methodologies for all stakeholders within a product's life cycle on how to share or take responsibility for reducing the environmental, social and economic impacts of products. It typically addresses five key themes, which are;

a. Life cycle management;
b. Design for sustainability;
c. Mitigation of environmental, social and health impacts;
d. Shared responsibility and stakeholder engagement; and,
e. Process and product innovation.

1.2 Aim of the interview programme

This stage of the research is aimed at understanding and examining the perception, feasibility and operation of product stewardship in the UK precast concrete industry. It is particularly targeted at experienced professionals in the field of sustainable construction and sustainability management; as an industry expert, we are inviting you to take part and help explore the potential offered by product stewardship for the precast industry. This will be done in two steps:

STEP ONE: A questionnaire survey - please complete the questionnaire prior to the interview. We will be able to discuss your responses when we meet, but this data is important for comparison and helping us to understand your company's needs.

STEP TWO: The interview – we will come and visit you at your convenience. The questions are shown in the latter pages of this document. We suggest that you review the questions in advance of the interview so that the process is smooth and efficient.

2. What happens now?

We will keep in touch with you to make arrangements to meet, but if you have any queries in the meantime, please contact:

Abdullahi A. Aliyu, Research Engineer, British Precast/Loughborough University (email: abdullahi.aliyu@britishprecast.org) Tel: 0116 253 6161, Fax: 0116 251 4568.

STEP ONE: Self-completion Questionnaire

Please complete Questions 1-15 prior to the arranged interview appointment.
Thank you very much.

1. How are the current sustainability initiatives of the UK precast concrete industry directly affecting your business processes within your company (please provide details below):

2. To what extent are current methods for the 'life cycle management' of precast concrete products suitable and sustainable? Please make one tick per row in the table below.

Scale	**Key to 1-5 scale:** 1 = Not important 2 = Fairly important 3 = Important 4 = Strongly important 5 = Extremely important

	1	**2**	**3**	**4**	**5**
Life cycle assessment					
Life cycle costing					
Recycling					
Reuse					
Takeback					
Material recovery					
Material collection					

3. Which product(s) groups best describes your market offering(s)?

4. Which markets does your company mainly supply to? Please circle one below.
   a. Housing
   b. Public buildings
   c. Bridges, box culverts, beams, cladding panels
   d. If other, please specify ____________________________

5. Please describe your customers' typical reactions to the following sustainability policies and standards.

	Customers' reactions
Environmental Management Systems	
Code for Sustainable Homes	
BS8902	
BES 6001	
PAS2050	
Green Guide Rating	
CRC Energy Efficiency Scheme	

6. Is your company involved in the CRC Energy Efficiency Scheme?

Yes/ No

7. Do you currently have a contract/agreement with any third-party haulage and logistics companies?

Yes/ No

8. The following parties all have a stake in the sustainability impacts ultimately caused by construction materials. To what extent do you think each of them has such an effect? Please indicate below what share (of 100%) each of these parties has. For example if you think contractors cause 100%, then write 0% for the remainder of the stakeholders, or if you think they have an even share, then write 20% for each).

   a. *Designers* ....%
   b. *Suppliers* ....%
   c. *Contractors* ....%
   d. *Clients* ....%
   e. *Manufacturers* .... %
   f. *Government* ....%
   g. *Users* .... %
   h. *Others* .... %

9. Are there any markets that you currently can't sell into because of a lack of sustainability credentials (e.g. because your company does not have BES 6001 or ISO 14001 or similar)?

Yes/ No

If YES, please state:

---

10. Do you think the following sustainability approaches in the management of environmental, social and economic impacts of the UK precast concrete industry are sufficient to achieve sustainability? Please make one tick per row in the table below.

Scale	**Kay to 1-5 scale:** 1 = Not important 2 = Fairly important 3 = Important 4 = Strongly important 5 = Extremely important

Environmental	**1**	**2**	**3**	**4**	**5**
Environmental Management System					
Waste Minimisation					
Emissions (excluding CO2)					
Quality and performance					
Energy Efficiency					
Emissions (production and transport)					
Material Efficiency embodied impacts (cements e.t.c)					
Mains water					
Site stewardship and Biodiversity					

Please make one tick per row in the table below.

Social	**1**	**2**	**3**	**4**	**5**
Health and Safety					
Employee satisfaction					
Employment and skills					
Local communities					
Respect for people					

Please make one tick per row in the table below.

Economic	**1**	**2**	**3**	**4**	**5**
Contracts awarded and executed					
Productivity					
Annual profits after tax/ revenues					
Cost of all goods, materials and services					
Taxes paid					
Penalties and liabilities					

11. In your opinion what is the most effective driver for initiating change within the UK precast concrete industry? Please circle ONE only.

a. Voluntary commitments
b. Legislation
c. Clients demands
d. Economic benefits
e. Environmental consideration

Why is this?

____

12. Has your company experienced a dip in profits/revenues as a result of the recent economic recession in the UK?

Yes/ No

13. In your opinion what is the most significant barrier or challenge to change within the UK precast concrete industry? Please circle ONE only.

a. Skilled man power and expertise
b. Cost
c. Lack of a strategy
d. Lack of interest
e. If other, please specify _

14. Have you considered having an independent third party recognised LCA assessment of your products and or full or part of your operation(s).

Yes/ No

If YES, please explain what were the drivers for that decision?

15. In 20 words or fewer, please describe your vision for 'a more sustainable precast concrete industry'

STEP TWO: Interview questions

SECTION 1: PRODUCT STEWARDSHIP FOR THE PRECAST INDUSTRY

a. **Understanding: What do you understand by the term 'product stewardship'?**

- Are you conversant with the term PS before this interview?

PRESENT (MODEL1 - 4) TO INTERVIEWEE PRODUCT STEWARDSHIP SUPPLY CHAIN

- Which model best describes or might likely work for your company?

b. **Do you have a policy or system in place to manage and mitigate all your company's life cycle impacts i.e. environmental, social and economic impacts?**

- Are there any life cycle considerations made during product design, development and production?
- How do you balance sustainability requirements with your clients' needs and other downstream stakeholders?
- Do you talk with your upstream suppliers on sustainability and the impacts of their products? Do they address these voluntarily or mandatory?
- Were there any steps taken by your company on embodied or inherited impacts upstream the supply chain?
- Do you have any procedure or policy that focus on mitigating your products impacts after leaving the factory gate, post construction and end-of-life? How realistic do you find such procedures?

c. **Are you currently involved in any product stewardship initiative(s) within your company?**

- Do you have a policy or system in place to manage and mitigate all your company's life cycle impacts i.e. environmental, social and economic impacts? For example Life cycle studies, responsible sourcing e.t.c.
- what were the main drivers for developing this initiative your company?
- Can you give examples of any initiative within or outside the industry or in any other company?
- Where you able to get external support or help from experts, an organisation, government or any non-governmental organisation?
- What are you clients perception to issues such as life cycle management and responsible sourcing? Do you think these things are good for business? And why?

d. **Development: Do you see the possibility or feasibility of a PS initiative in your company?**

- In your opinion do you think a PS scheme for the precast concrete industry should be Mandatory or voluntary?
- Do you think that collaborative or individual company approach to such an initiative will be more effective in terms of performance, service delivery and implementation?
- If clients are not enthusiastic about PS would you consider taking part in any PS initiative?
- Is the UK precast concrete industry ready for a PS scheme or initiative?
- How realistic is a PS initiative be? i.e. a scheme, programme, framework or road map e.t.c. Will a PS scheme for the industry be accepted, rejected or well received in the industry?

e. **How important is 'product stewardship' to your company?**

- Do you think implementing PS will affect your current targets e.g. cement targets, strength of products e.t.c. (positively or negatively).

f. **What benefits do you envisage that a 'product stewardship 'programme/ scheme or framework**

SECTION 2: OPERATING PRODUCT STEWARDSHIP

g. What aspects do you think a typical precast concrete industry product stewardship initiative might include?

- Who should manage a PS scheme or initiative for the precast concrete industry?
- Which areas would you like to see more focus, attention or emphasis given if and when a framework or scheme is put in place?

h. Current targets: Do you think the current precast concrete industry targets can be met by 2012?

- Why do you think the targets can be or can't 'be met?

i. Leadership: Who do you think should take responsibility for 'product stewardship' in UK precast companies?

- Who is responsible of the impacts created from your product from sourcing to end-of-life?

SHOW TABLE

- Is there a need for incentive from government or other regulatory agencies like WRAP, Environment

Please tick only the correct answer applicable to your company and provide any further comments in the rows provided.			
From a life cycle perspective, your company is involved and responsible in;			
Generic life cycle stages of precast concrete products	**Yes**	**No**	**Comments**
Sourcing of constituents materials			
Sourcing of additives and enhancers			
Design and development of product			
Production			
Transport, delivery and logistics			
Construction and installation			
Maintenance			
End-of-life; recovery, reuse, recycle			

Agency e.t.c?

- Do you think the industry has the skill and technical know-how to run an effective PS initiative? If yes or no, why do you think so?

j. Consultation: What are the most effective means of building consensus on 'product stewardship' in the UK precast concrete industry?

- Do you engage with your suppliers about sustainability, embodied impact and responsible sourcing?
- What kind of close collaboration and communication do you have with upstream suppliers to support responsible sourcing?
- What kind of close collaboration and communication do you have with downstream users to support responsible sourcing?

SECTION 3: YOUR VIEWS ON CURRENT PROGRAMMES

k. What more can the precast concrete industry do to mitigate its key environmental, social and economic impacts?

- Is there any evidence(s) you have to support your views?
- Do you think that the current industry initiatives and programmes on sustainability are sufficient to make the industry sustainable?
- Can you explain further why you think so?

COMMENTS AND FURTHER INFORMATION

Your views are welcome on this report and our approach to developing a more sustainable precast industry. For further information and enquiries about the Product stewardship project, please contact Abdullahi.aliyu@britishprecast.org or A.A.ALIYU@LBORO.AC.UK

APPENDIX F Focus Group/ Short Questionnaire Survey

FOCUS GROUP/ SHORT QUESTIONNAIRE SURVEY

List of questions to be think about when reading the framework developed for the UK precast concrete industry

Question	Answer	
1. Does this EPD framework potentially look useful to your company? If yes/ no please give reasons		
1a. Are you happy with the long validation/ 3rd party accreditation process? Could it be expensive to you?		
1b. Are you comfortable with this EPD governance structure?		
1c. Do you think it will be implemented?		
1d. How useful will this EPDS framework be to your clients?		
2. Are there any aspect(s) or area(s) you don't understand or unclear about?		
2b. Is there anything missing in the content of the EPDS?		
2c. Is the role of the programme operator or consultant clear?		
2d. Is the nature of data exchange process, EPDS produced clear? And the linkages between the difference stages coherent?		
2e. Can you think of any technical or managerial difficulties not being addressed explicitly?		
2f. Do you think the EPDS framework is balance in regards to apportioning of responsibilities within all the stages of the framework A-E?		
3. What are the critical aspect(s) and area(s) within the framework to your company?		
- Cost?		
- Training requirements?		
- BREEAM credits?		
- Recognition by clients?		
- Possible legislation?		
- We don't care about EPDs?		
4. Are you willing to discuss this in confidence through an interview, a focus group or through other convenient medium to you? Please tick Yes/ No	Yes	No

INTERVIEW TRANSCRIPT

Questions	Companies					
	CPM Group	**CR Longley**	**Hanson Building Products**	**Forticrete**	**Marshalls PLC**	**Stanton Bonna**
1. Does this EPD framework potentially look useful to your company? If yes/no please give reasons	Possibly - In relation to the sustainability data collection- It may help in monitoring our processes with regards to our environmental impacts	Yes	Yes, it seems like an effective route to certification without a lot of the "noise"	Yes - the framework lays at a structure of how to comply to complicated areas	Yes - having an industry-wide standard methodology is important so we are all on an even playing field. This framework looks reasonable	Yes
1a. Are you happy with the long validation/ 3rd party accreditation process? Could it be expensive to you?	Not sure - cost - effectiveness	Any accreditation process is expensive, the longer the more expensive	It is dependent on cost. If the process takes less than a couple of months with minimal input	Concerns with overall cost and benefit	Not really! But these things take time. The costs must be proportionate. Manufacturers produce vast numbers of products. The cost could be prohibitive (carbon footprints for example)	Imagine it could be expensive
1b. Are you comfortable with this EPD governance structure?	Happy with structure	Yes	Yes	Yes	Yes	
1c. Do you think it will be implemented?	I think it will be implemented	No	Dependent on cost and whether competitive	Not sure	Yes	Don't know
1d. How useful will this EPDS framework be to your clients?	Very useful for our clients to realise we do take our responsibility regarding EPDs seriously	I do not think the EPDS framework will be useful to clients	Not relevant at the moment- depends on whether its on their radar	Very, they seem very interested in this area	They will become increasingly important, especially as they are driven by legislation	Don't know
2. Are there any aspect(s) or area(s) you don't understand or unclear about?	Realise we do take our responsibility regarding EPDs seriously	Yes	No-although there are no timetables or costs	Very new to subject matter - given some basic information of what EPDs are - potential impacts	Seems reasonably clear. I'm not 100% up to date with all of this because my investigation on the subject has been limited. I will read more...?	Yes
2b. Is there anything missing in the content of the EPDs?	Think everything is covered	Not to my knowledge	No seems to be complete	Not have enough experience to evaluate	Not that I can see.....	Don't know

2c. Is the role of the programme operator or consultant clear?	Clear to establish their responsibilities	Yes	Yes	Yes	Yes	Yes
2d. Is the nature of data exchange process, EPDS produced clear? And the linkages between the difference stages coherent?	Acceptable	Yes	All of the areas appears to be covered	Yes	I am not entirely up to speed but I think I understand	Don't know
2e. Can you think of any technical or managerial difficulties not being addressed explicitly?	I think the data addresses what is required	Not at the moment	No	No - limited experience to make judgement	I suppose the collection of data will be demanding on managerial time. I think this has been covered though.	Don't know
2f. Do you think the EPDS framework is balance in regards to apportioning of responsibilities within all the stages of the framework A-E?		Yes	Yes	As above	Yes. Though there isn't much mention of the manufacturer. It is these people who will be providing a lot of information	Don't know
3. What are the critical aspect(s) and area(s) within the framework to your company?	I think the order on the left (i.e. below) is how I see the importance			All below indicated but with varying degrees	Unless the data has been considered in the BPCF KPIs already?!	Cost, Recognition by clients
Cost?		Very important	The key aspects are costs, BREEAM and legislation - Training is probably more important to the customer		All with the exception of BREEAM credits.	
Training requirements?		Need to be carefully considered				
BREEAM credits?		?				
Recognition by clients?		Not important yet				
Possible legislation?		Yes could be				
We don't care about EPDs?						

CODING, CATEGORISATION AND PATTERNS IDENTIFICATION

Questions	Categories
	Responses to the questions were sorted into:
1. Does this EPD framework potentially look useful to your company? If yes/ no please give reasons	Yes (Y), possibly (P), effective route to certification (CER), complies to complicated areas (COMP), governance (GOV), 15804 compliant (COM), sector approach (SEC), standard methodology with level playing field (Stan. Meth)
1a. Are you happy with the long validation/ 3rd party accreditation process? Could it be expensive to you?	Not clear (NCL), time (T), cost (C), shorter timescales (STS)
1b. Are you comfortable with this EPD governance structure?	Yes (Y), Credible, transparent and effective governance structure (GOV. STRC)
1c. Do you think it will be implemented?	Yes (Y), no (N), don't Know (DK), not sure (NS), cost (C)
1d. How useful will this EPDS framework be to your clients?	Provides reassurance (PR), very useful (VU), not useful (NU), not Relevant (NR), don't know (DK)
2. Are there any aspect(s) or area(s) you don't understand or unclear about?	Yes (Y), product category rules (PCR), cost (C), timescales (TS), potential impacts (PI), new to subject (NS), limited in Subject (LS), technical and specialist terms (T&ST), LCA(LCA)
2b. Is there anything missing in the content of the EPDs?	No (N), not to my Knowledge (NTK), don't know (DK) everything is covered (EC)
2c. Is the role of the programme operator or consultant clear?	Yes (Y)
2d. Is the nature of data exchange process, EPDs produced clear? And the linkages between the difference stages coherent?	Yes (Y), don't know (DK), acceptable (A), all areas covered (AAC), not up to speed (NUS)
2e. Can you think of any technical or managerial difficulties not being addressed explicitly?	No (N), data addressed what's required (DAT), limited experience to comment (LE), don't know (DK)
2f. Do you think the EPDS framework is balanced in regards to apportioning of responsibilities within all the stages of the framework A-E?	Yes (Y), limited experience to comment (LE), don't know (DK), manufacturers should be included (MAN)
3. What are the critical aspect(s) and area(s) within the framework to your company?	Cost(c), training requirements (TR), legislation (L), BREEAM (BR), EPDs not needed (ENN), recognition by clients (RC)
Cost?	
Training requirements?	
BREEAM credits?	
Recognition by clients?	
Possible legislation?	
We don't care about EPDs?	

Note: Codes and abbreviations are in brackets

KEY ISSUES, THEMES AND PATTERNS

1. The EPDs framework developed has the potential of being useful to member companies as it can provide:
   - A level playing field standard methodology that has a sector base approach;
   - It can facilitate an effective route to certification;
   - It is relevant to standards e.g BS15804.

   a. The long validation/ third party accreditation process is not very clear with timescales; cost has been identified as a major factor.
   b. Governance structure is accepted and should be credible, effective and transparent
   c. In terms of implementation, there was a mixed feeling while some aren't sure others feel it can be implemented
   d. Some respondents mentioned that the EPDs framework is very useful and provides reassurance of meeting relevant standards while others aren't sure due to their limited knowledge in the subject area.
2. Areas listed by respondents as unclear include; Product category rules (PCR), estimated cost, timescales, issue of LCA, the use of technical and specialist terms, lack of full knowledge in subject area.
   b. There weren't any specific areas identified by respondents as missing in the EPDs framework
   c. The role of the programme operator and consultant seems to be clear
   d. Some respondents are of the opinion that the nature of data exchange process, the EPD framework, and the linkages between different stages of the framework are coherent while other have little knowledge in the subject area to comment
   e. The EPDs framework seems to address certain technical and managerial issues.
   f. The EPDs framework has been able to address the issue of apportioning responsibilities within stages A-E of the framework, however manufacturers have been identified as most suited to provide product information
3. The critical areas identified within the framework recorded a mix reaction but include;
   a. Cost
   b. Training requirements
   c. BREEAM
   d. Legislation

Key words
Certification (CER), complies to complicated areas (COMP), governance (GOV), 15804 compliant (COM), sector approach (SEC), standard methodology with level playing field (Stan. Meth), time (T), cost (C), shorter timescales (STS), Product category rules (PCR)

Keywords related to PS literature
Cost (C), sector approach (SEC), standard methodology with level playing field (Stan. Meth), time (T), Legislation (L), governance (GOV), Credibility and recognition by clients (CRC)

RESEARCH QUESTIONS FOR INTERVIEWS

1. What are the UK precast concrete industry's specific requirements and peculiarities for EPD?
2. How does an EPD for precast concrete product looks like?
3. When should EPD be implemented or developed?
4. What are the immediate, short term and long term benefits of EPD for the industry?
5. What are the opportunities, challenges and threats for EPD?
6. What are the system boundaries for EPD implementation in relation to possible associate risks, problems and barriers?
7. What are most effective and acceptable means of developing EPD by the industry?
8. Who should be involved in the development and management of EPD within and outside the industry?
9. How can we avoid a complexity and expense of LCA, Especially of a wide-scale project such as entire sector EPD?
10. Who should govern an EPD Scheme and how could it be run?
11. Who is the best to certify, verify, calculate and govern/oversee the whole scheme? Do we need a third party auditor for the scheme?
12. How can an EPD scheme fit in within a wider product stewardship scheme?
13. How many EPDs will be required by the precast concrete industry to cover all products within the industry? How can they relate to each other or harmonised into a complete scheme?
14. What are the structures, data and instruments needed to support the effective and efficient development and delivery of EPD?
15. What are the likely scenarios for the future of EPD and the next step after EPD?
16. Are there any risks and threats as a result of EPD development and implementation?

INTERVIEW TRANSCRIPT

Interviewer: Abdullahi Aliyu, Research Engineer, Loughborough University

Interviewee A: Mr. S **Company: Company** A **Position:** Head of Sustainability

Interviewee B: Mr. D **Company: Company** B **Position:** Environment and sustainability manager

Research questions and answers

Interview questions:	**Company A** **Interviewee answers**	**Company B** **Interviewee answers**
Interviewer: What is the UK precast concrete industry's specific requirements and peculiarities for EPD?	**Interviewee:** *Blended cements and admixtures*	**Interviewee:** *One of the difficulties will be allocation of impacts on sites which produce moiré than one type of product*
Interviewer: How does an EPD for precast concrete product looks like?	**Interviewee:** *A series of tables, perhaps not as easy to use as a single metric*	**Interviewee:** *The content of the EPD is dictated by the standard*
Interviewer: When should EPD be implemented or developed?	**Interviewee:** When there is a legislative requirement	**Interviewee:** *Difficult to say as there are no regulatory drivers – short term it is a way of reporting Carbon Footprint data to customers and establish methodologies for accurate data collection.*
Interviewer: What are the immediate, short term and long term benefits of EPD for the industry?	**Interviewee:** Short term is about compliance, long term is difficult to say as policy and market drivers will change	**Interviewee:** *Benefits are in being seen as a leader*
Interviewer: What are the opportunities, challenges and threats for EPD?	**Interviewee:** There is a risk that it becomes a stick if made compulsory and then the value proposition will become eroded	**Interviewee:** *The biggest threat is in making it too difficult and expensive*
Interviewer: What are the system	**Interviewee:** 2 questions here-clarify what you want	**Interviewee:** *This will be defined by the PCR*

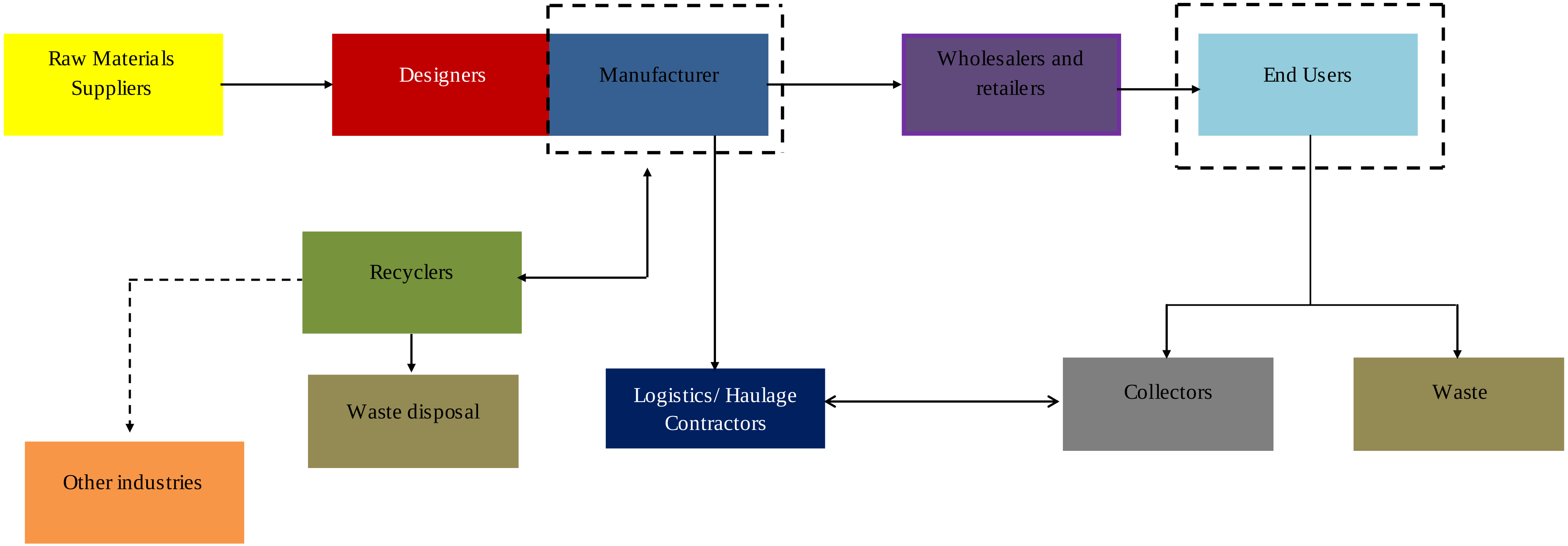
boundaries for EPD implementation in relation to possible associate risks, problems and barriers?		
Interviewer: What are most effective and acceptable means of developing EPD by the industry?	**Interviewee:** Generic- trade body lead	**Interviewee:** *Not sure what you mean by this – the content of the EPD is defined by the PCR*
Interviewer: Who should be involved in the development and management of EPD within and outside the industry?	**Interviewee:** Members of BPCF and key consultant	**Interviewee:** *Inside the industry – Upstream supply chain* *Outside the industry – Programme Operators/Verification bodies.*
Interviewer: How can we avoid a complexity and expense of LCA, Especially of a wide-scale project such as entire sector EPD?	**Interviewee:** You have answered your own question here.	**Interviewee:** *A free market leading to adequate supply. Simple process*
Interviewer: Who should govern an EPD Scheme and how could it be run?	**Interviewee:** Scheme operator, governance, third party verification	**Interviewee:** *Sector Association*
Interviewer: Who is the best to certify, verify, calculate and govern/oversee the whole scheme? Do we need a third party auditor for the scheme?	**Interviewee:** Yes in the end but not straight away, self-declaration is the first step	**Interviewee:** *The ability to have the EPD third party verified is essential.*
Interviewer: How can an EPD scheme fit in within a wider product stewardship scheme?	**Interviewee:** It can grow to become the same thing	**Interviewee:** *This is dependent on the complexity of supply chain.*
Interviewer: How many EPDs will be required by the precast concrete industry to cover all products within the industry? How can they relate to each other or harmonised into a complete scheme?	**Interviewee:** 2- reinforced and not	**Interviewee:** *Not able to answer this – dependent on Market.*
Interviewer: What are the structures, data and instruments needed to	**Interviewee:** Technical knowledge balanced with a practical and realistic approach. Need to manage	**Interviewee:** This is dependent on the nature of the business – the most important aspect is the ability to

support the effective and efficient development and delivery of EPD?	costs well and a transparent model.	identify data at product rather than site level.
Interviewer: What are the likely scenarios for the future of EPD and the next step after EPD?	**Interviewee:** Reluctance - acceptance - use - value adding	**Interviewee:** *Too early in the process to guess*
Interviewer: Are there any risks and threats as a result of EPD development and implementation?	**Interviewee:** The rate of deployment; timing is key	**Interviewee:** The biggest risk is that you invest in the process and find that your product is the worst performing in its sector.

APPENDIX G PS Models developed

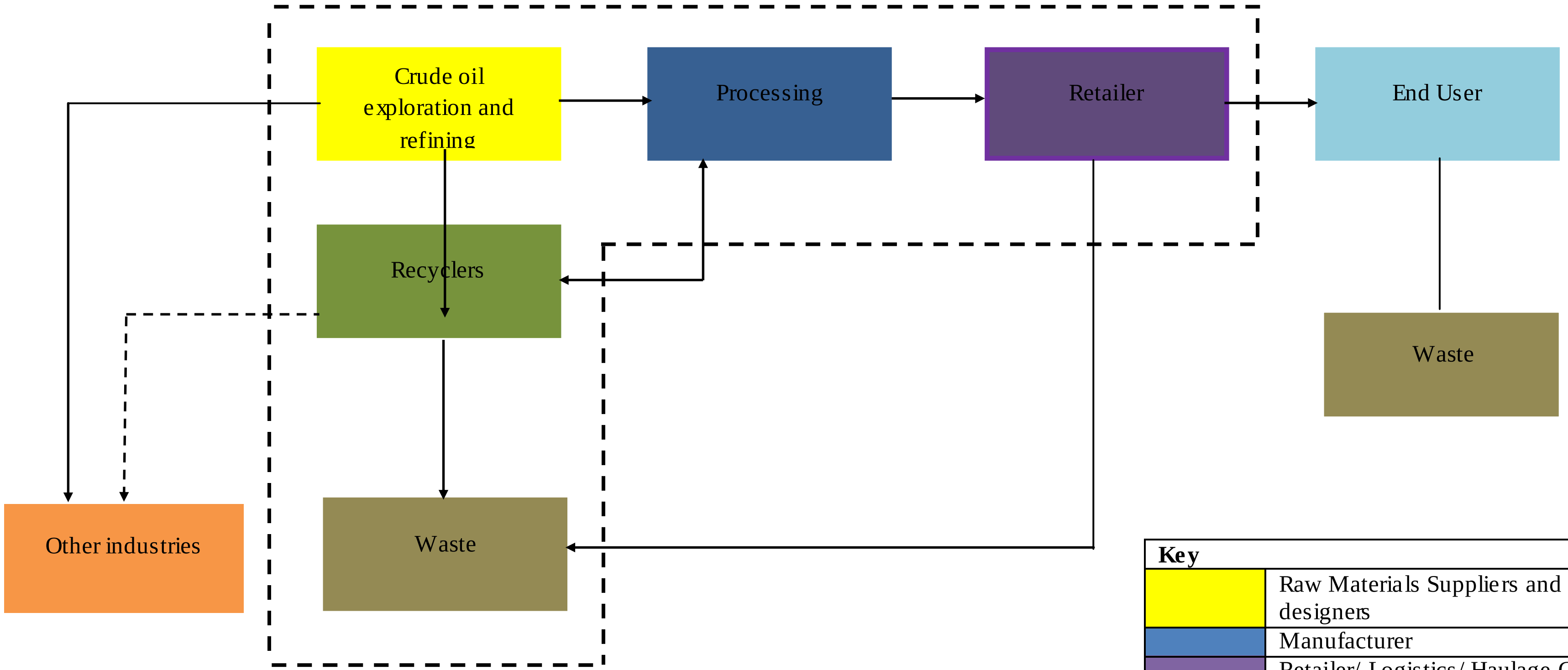
MODEL 1: Automotive industry (e.g. trucks, cars etc)

Relevant regulation: European Commission End-of-Life Vehicles (ELV) Regulation 2010



Key	
	Raw Materials Suppliers
	Designers
	Manufacturer
	Retailer
	Collectors
	Other industries
	Logistics/ Haulage Contractors
	Waste
	End User
- - - -	Stakeholder Responsibility

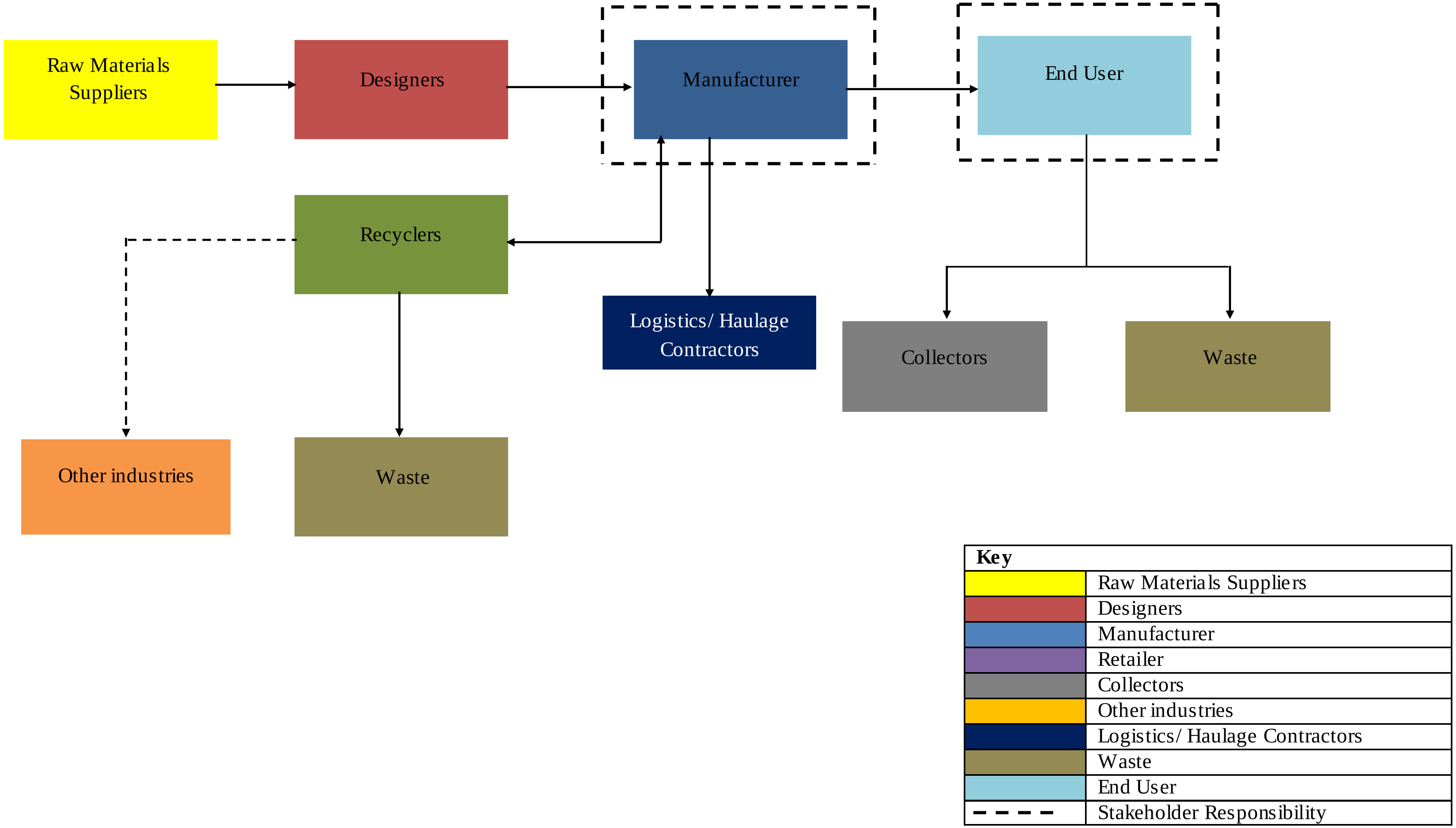
MODEL 2: Oil and Gas industry- (e.g. gas)



Key	
	Raw Materials Suppliers and engineers, designers
	Manufacturer
	Retailer/ Logistics/ Haulage Contractors
	Other industries
	Waste
	End User
- - - -	Stakeholder Responsibility

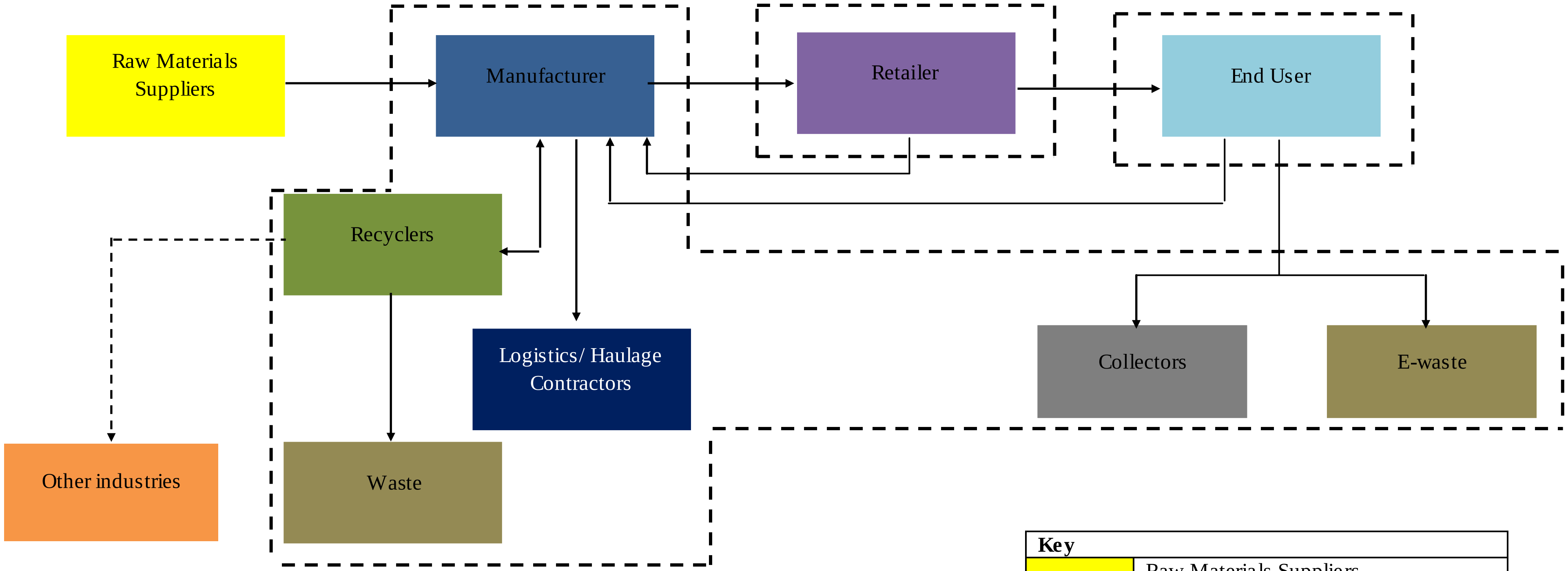
MODEL 3: Packaging industry (e.g. carton packaging)

Relevant regulation: 1994 European Union directive on packaging and packaging waste/producer responsibility obligations (Packaging Waste)



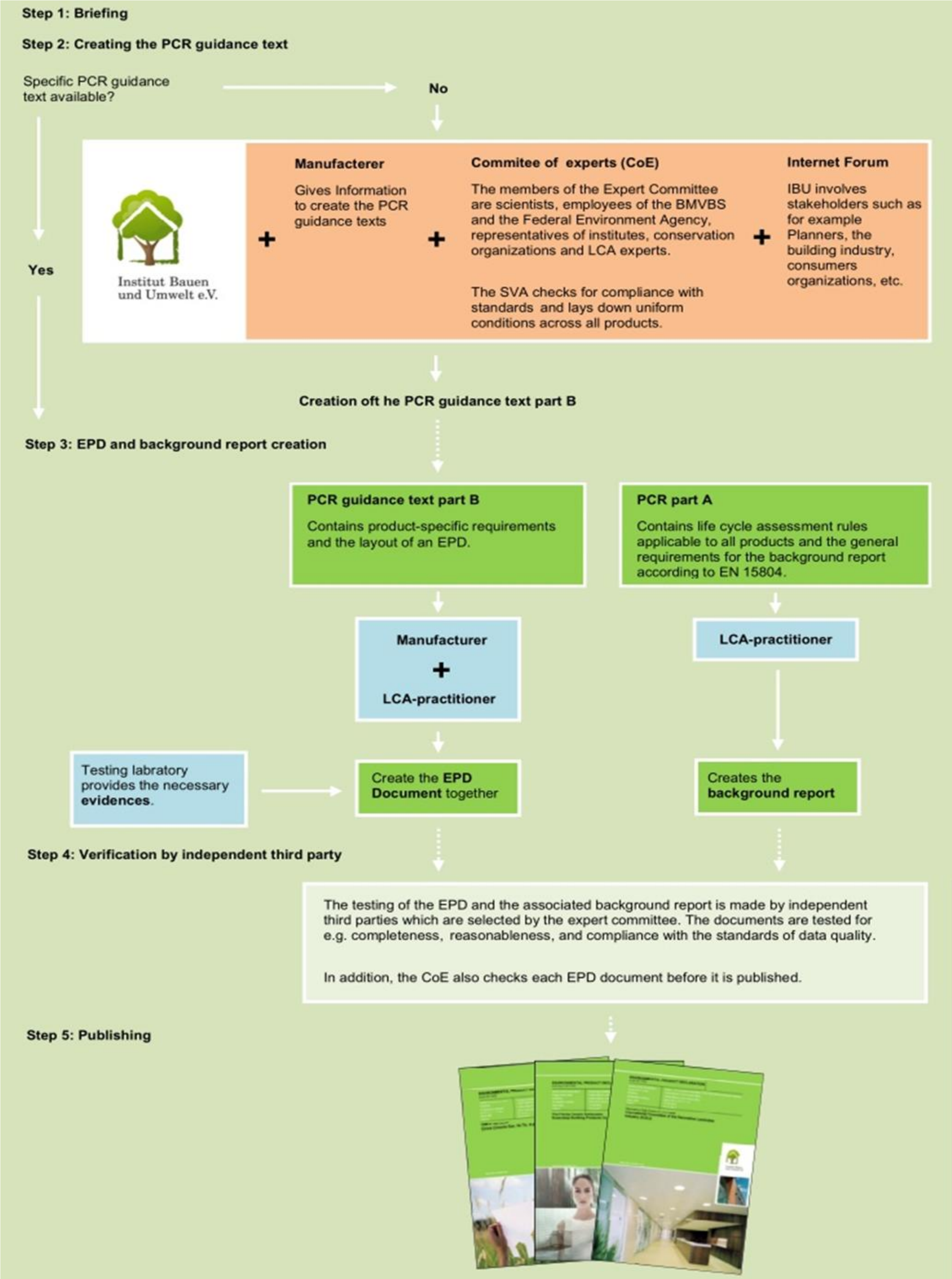
MODEL 4: Electric and electronic industry (e.g printers, printer cartridge, computers, etc)

Relevant legislation: the Waste Electrical and Electronic Equipment Directive (WEEE Directive).



Key	
	Raw Materials Suppliers
	Designers
	Manufacturer
	Retailer
	Collectors
	Other industries
	Logistics/ Haulage Contractors
	Waste
	End User
- - - -	Stakeholder Responsibility

APPENDIX H: EPD creation stages according to IBU, Germany



Source: Institute for Construction and Environment (IBU, 2014). https://epd-online.com/

APPENDIX I: LCA results of Cement EPD published by the UK Cement industry

LCA: Results

The tables below give the LCA results for environmental impacts, resource use as well as output flows & wastes categories for the modules that are declared in this study.

DESCRIPTION OF THE SYSTEM BOUNDARY (X = INCLUDED IN LCA; MND = MODULE NOT DECLARED)

PRODUCT STAGE			CONSTRUCTION PROCESS STAGE		USE STAGE							END OF LIFE STAGE				BENEFITS AND LOADS BEYOND THE SYSTEM BOUNDARYS
Raw material supply	Transport	Manufacturing	Transport from the gate to the site	Assembly	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction demolition	Transport	Waste processing	Disposal	Reuse-Recovery-Recycling-potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
X	X	X	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND

RESULTS OF THE LCA - ENVIRONMENTAL IMPACT: UK Average Portland Cement/ 1 tonne

Parameter	Unit	A1 - A3
Global warming potential	[kg CO_2-Eq.]	846
Depletion potential of the stratospheric ozone layer	[kg CFC11-Eq.]	7.28E-6
Acidification potential of land and water	[kg SO_2-Eq.]	1.82
Eutrophication potential	[kg $(PO_4)^{3-}$- Eq.]	0.243
Formation potential of tropospheric ozone photochemical oxidants	[kg Ethen Eq.]	0.175
Abiotic depletion potential for non fossil resources	[kg Sb Eq.]	0.002
Abiotic depletion potential for fossil resources	[MJ]	3490

RESULTS OF THE LCA - RESOURCE USE: UK Average Portland Cement/ 1 tonne

Parameter	Unit	A1 - A3
Renewable primary energy as energy carrier	[MJ]	121
Renewable primary energy resources as material utilization	[MJ]	0
Total use of renewable primary energy resources	[MJ]	121
Non renewable primary energy as energy carrier	[MJ]	3790
Non renewable primary energy as material utilization	[MJ]	0
Total use of non renewable primary energy resources	[MJ]	3790
Use of secondary material	[kg]	41.9
Use of renewable secondary fuels	[MJ]	178
Use of non renewable secondary fuels	[MJ]	1110
Use of net fresh water	[m³]	0.451

RESULTS OF THE LCA – OUTPUT FLOWS AND WASTE CATEGORIES: UK Average Portland Cement/ 1 tonne

Parameter	Unit	A1 - A3
Hazardous waste disposed	[kg]	0.004
Non hazardous waste disposed	[kg]	9.12
Radioactive waste disposed	[kg]	0.121
Components for re-use	[kg]	0
Materials for recycling	[kg]	0
Materials for energy recovery	[kg]	0
Exported electrical energy	[MJ]	0
Exported thermal energy	[MJ]	0

Source: Mineral Products Association (2014). UK Cement Industry Publishes Leading Environmental Product Declaration (EPD). [Online]. Available at: http://cement.mineralproducts.org/documents/UK_Average_Portland_Cement_EPD.pdf. Accessed on: 11th March, 2014.

APPENDIX J: EngD research project summary flier

Why do we need EPD?

Product manufacturers are becoming more aware of stakeholders' increasing demands and pressure regarding the need to declare, communicate and transmit the environmental credentials and information of products and services.

One of the most effective and innovative ways to achieve this is through the use of EPD. The key aim of EPD is the systematic communication of environmental information of a product, good and service that is reliable and accurate such that it encourages the need and supply of products and service with less environmental stress.

The focus on EPD for the precast concrete industry was born out of the need to improve on its sustainability performance and stewardship of its products and service. EPD can provide stakeholders (within and outside the construction industry) with accurate, third party verified environmental information about products and help clients and designers with product or material comparisons (e.g. the choice of a precast concrete product over steel, timber or glass equivalent).

A model for precast concrete manufacturers

As part of an overarching PS initiative or scheme for the precast concrete industry, EPD development can offer an appropriate starting point for the mitigation of key environmental impacts.

A generic model for the UK precast concrete has been developed (with representation of the entire supply chain, from raw material extraction/supply, design, manufacture, wholesale/ retail, use, through to end-of-life.

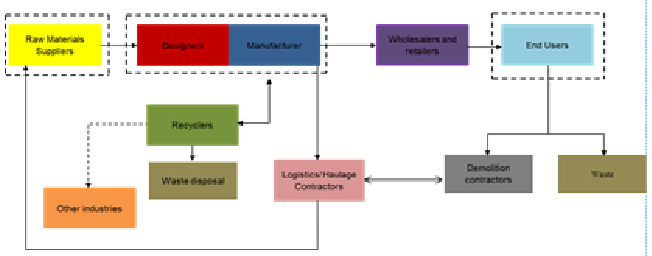


Figure 4: A generic model for UK precast concrete

The UK precast concrete industry has an opportunity to develop an industry-wide EPD which can be centralised and managed by the trade federation with third-party independent verifiers as PCR management consultants. This will help the industry to voluntarily market its green credentials in a more effective manner while also reducing its environmental footprints/impacts.

However, the EPD must also be valid at company level., so while sector bodies within the industry can be instrumental, it will be a matter for the individual precast concrete member companies to invest in developing their own product-level EPDs.

Acknowledgement

Special appreciation goes to all the individuals and companies that made this research possible, as well as the sponsors of the Engineering Doctorate (EngD): the Engineering and Physical Sciences Research Council (ESPRC), Loughborough University and British Precast Concrete Federation.

References

1. Aliyu, A.A. (2014). Product Stewardship as a Novel Sustainability Pathway for the UK Precast Concrete Industry. EngD thesis. Loughborough University.
2. BSI. (2014). BES 6001 Responsible Sourcing of Construction Products. [Online]. Available at: http://www.bsigroup.com/en-GB/bes-6001-responsible-sourcing-of-construction-products/. Accessed on: 16th March, 2014.
3. BSI. (2014). EN 15804:2012+A1:2013 - Sustainability of construction works — Environmental product declarations — Core rules for the product category of construction products. London: British Standard Institution.
4. BS EN 15804. (2012). Sustainability of construction works. Environmental product declarations. Core rules for the product category of construction products. London: British Standard Institution. (Now withdrawn and superseded by EN 15804:2012+A1:2013).
5. Manzini, R., Giuliano N., Massimiliano O. and Emanuele P. (2006). Assessing Environmental Product Declaration Opportunities: a Reference Framework. Business Strategy and Development 15 (2) pp. 118–134.
6. Kylakorpi, L., Bodlund, B. and Setterwall, C. (2007). LCA – A basis for environmental stewardship in the power industry, The Society of Environmental Toxicology and Chemistry.
7. Erlandsson, J. and Tillman, A-M. (2009). Analysing influencing factors of corporate environmental information collection, management and communication. Journal of Cleaner Production, Vol. 17, pp. 800–810.
8. Fava, J., Baer, S. and Cooper, J. (2011). Green(er) product standard trends in North America. Journal of Industrial Ecology, Vol.15, pp. 9-12.
9. Ingwersena, W.W and Martha J. Stevenson, M.J. (2012). Can we compare the environmental performance of this product to that one? An update on the development of product category rules and future challenges toward alignment. Journal of Cleaner Production.Vol.24, pp. 102–108.
10. IBU. (2014). UK Average Portland Cement Mineral Products Association (MPA) UK. IBU - Institut Bauen und Umwelt e.V.Germany. [Online] available at: http://cement.mineralproducts.org/documents/UK_Average_Portland_Cement_EPD.pdf Accessed on: 27th August, 2014.
11. Optimat. (2008). Sustainable Construction Strategy for the UK Concrete Industry (SCSCI). Commercial in confidence. 2008.
12. Fet, A.M., Skaar, C. and Michelsen, O. (2009). Product category rules and environmental product declarations as tools to promote sustainable products: experiences from a case study of furniture production. Clean Technology and Environmental Policy, Vol. 11, pp. 201–207.

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Environmental Product Declarations: the first step to product stewardship in the UK precast concrete industry

The Engineering Doctorate (EngD) Research Project

This flier provides a summary on an EngD collaborative research project, conducted by Abdullahi Aliyu. It was based at Loughborough University's Center for Innovative and Collaborative Construction Engineering (CICE) and the British Precast Concrete Federation (BPCF), the UK's Trade Federation of Precast Concrete Manufacturers and a member of the Mineral Product Association (MPA).

The four year project focused on the scope for applying the principles of product stewardship (PS) as a means to mitigate economic, environmental and social impacts associated with precast products and their associated services, throughout the entire life-cycle of their use.

What is Product Stewardship (PS)?

Product stewardship is about the precast concrete industry and its key stakeholders taking responsibility to mitigate the key economic, environmental and social impacts of products throughout their life cycle from cradle to cradle.

Why is it relevant to Precast Concrete Manufacture?

One of the distinguishing features of PS is that multiple stakeholders need to take responsibility for their 'share' of economic, environmental and social impacts, and that life-cycle thinking should pervade the value chain. So, through PS, the precast industry might be able to address not only the impacts within cradle-to-gate phases, but also develop a framework to act positively on broader, cradle-to-grave impacts.

Current and Future Drivers of PS

Product manufacturers are aware of stakeholders' increasing demands and pressure regarding the need to declare, communicate, and transmit the environmental credentials and information of products and services.

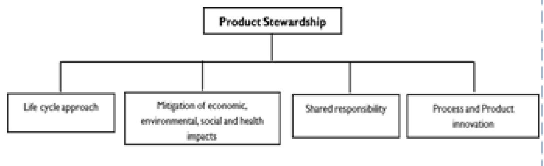

Figure 1: Key structural components of PS

Project sponsors:

mpa British Precast

Loughborough University
Centre for Innovative and Collaborative Construction Engineering

EPSRC
Engineering and Physical Sciences Research Council

The Lifecycle of Precast Concrete Products

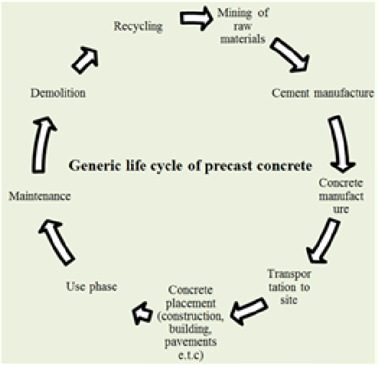

Figure 2: Generic lifecycle of precast concrete products

Sustainable Construction

The precast concrete industry has been very active in the area of sustainable construction through a series of initiatives devised by precast concrete companies and British Precast (the trade federation of precast concrete manufacturers).

Over the past decade, this has helped the industry in terms of: economic growth through investment in resources and manufacturing facilities; environmental protection such as the protection of coastlines with precast concrete products; social progress through the use of precast concrete in urban and regeneration projects (building infrastructure, public and private buildings); and the prudent use of natural resources through waste reduction, e.g. the extensive use of recycled materials.

The Role of Environmental Product Declarations (EPD)

The Construction Product Regulations (CPR), which came into effect in the UK on 1st July 2013, mandate that construction products placed in the market must provide information that is reliable and accurate with regards to their performance.

According to BSI, an **"EPD communicates verifiable, accurate, non-misleading environmental information for products and their applications, thereby supporting scientifically based, fair choices and stimulating the potential for market-driven continuous environmental improvement".**

Environmental product declarations (EPD) is also platform for embedding product stewardship in the precast concrete industry. EPD serve as specific means of communicating principally environmental information through the life-cycle lens. They are well-established within a range of product manufacturing paradigms across Europe and will enable precast manufacturers to compete by gaining points in sustainability assessment schemes like BREEAM and CEEQUAL.

Benefits to UK precast concrete manufacturers

⇒ **EPD provide all stakeholders, effective and innovative ways to achieve the systematic communication of environmental information through the life-cycle lens of a product, good or service that is reliable and accurate such that it encourages the need for and supply of, products and service with less environmental stress.**

⇒ **EPD provide companies with a cradle-to-grave approach that facilitates product stewardship throughout the value chain of the product**

⇒ **EPD provide a robust platform for making informed and educated comparison of products and services that perform similar or identical functions based on Life cycle assessment (LCA), predetermined product category rules (PCR) and international standards such as; ISO 14040.**

⇒ **EPD present credible, comparable, reliable and verified information.**

Example of EPD in the UK Concrete Industry

A typical example of an EPD closely related to the precast concrete industry is the first UK Average Portland Cement EPD published in February, 2014 by the Mineral Products Association (MPA) UK. This was verified and approved by the Institute for Construction and Environment (IBU) i.e Institut Bauen und Umwelt e.V.Germany.

The EPD provides an average covering all cement and clinker manufacturing sites and MPA cement member sites in Northern Ireland. The EPD was based on the average UK Portland Cement EPD data collected in 2011. All the major UK Cement manufacturing companies (CEMEX, Hanson UK, Lafarge Tarmac and Hope, UK) provided data from their sites across UK.

You can download a copy of the EPD at: http://cement.mineralproducts.org/documents/UK_Average_Portland_Cement_EPD.pdf

Five simple steps to EPD development for precast concrete manufacturers

⇒**STAGE 1:** Manufacturer decides to produce an EPD + Steering committee constituted which includes all key stakeholders (e.g. British Precast, LCA experts, sustainability/ environment managers, professionals and experts);

⇒**STAGE 2:** The Product Category Rules (PCR) are identified and the guidance documents are produced;

⇒**STAGE 3:** Life-cycle assessment data is gathered and processed, based on EN 15804, followed by any revision and/or testing of the EPD;

⇒**STAGE 4:** Verification and certification of the EPD by external, third party consultants; and, finally

⇒**STAGE 5:** the EPD can become publically accessible, usually as a download from the company's website.

EPD flow chart for the Precast Concrete Industry

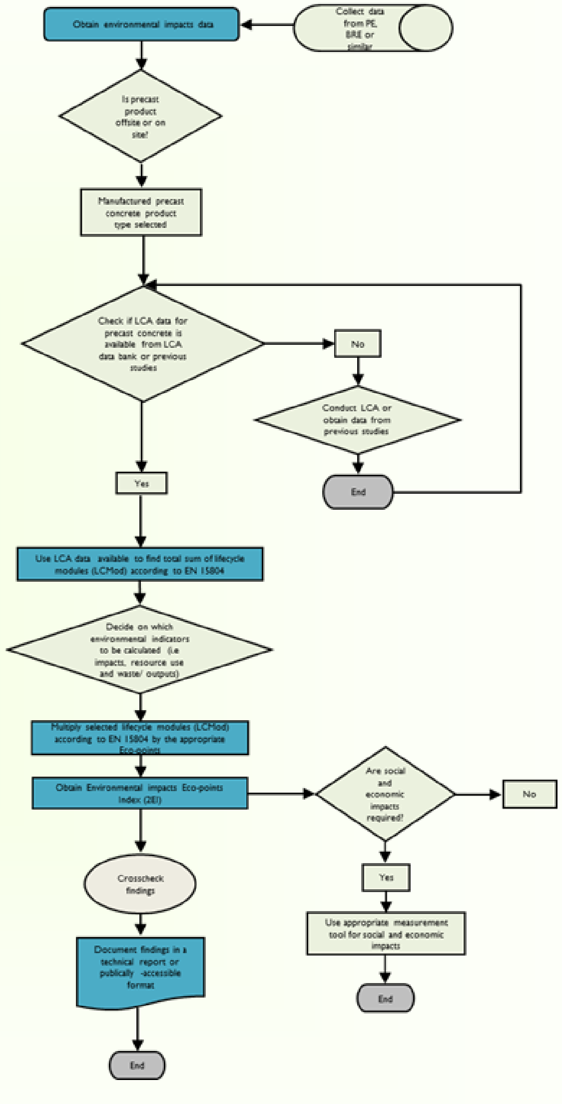

Figure 3: EPD flow chart for the Precast Concrete Industry