CRANFIELD UNIVERSITY

Amir Nazir

Enabling the Development of a Sustainability Best Practice Library

SCHOOL OF APPLIED SCIENCES

MSc THESIS

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ACADEMIC YEAR 2008/2009

Amir Nazir

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SUPERVISOR: Dr Ahmed Al-Ahsaab

SEPTEMBER 2009

This thesis is submitted in partial fulfilment of the requirements
for the Degree of Master of Science

ABSTRACT

Global environmental problems, rising energy prices, lack of raw material availability, increasingly demanding legislation and costly environmental taxes are some of the reasons that drive company policy towards adopting sustainability concepts and practices.

This MSc thesis project aimed to carry on the research of industrial sustainability best practices in order to have a detail documentation that will aid the development of digital library. This is to help companies like CEMEX and their stakeholders to increase their sustainability awareness and enabling them to embed best practices in their operational processes.

The research lacked clear and coherent method for mapping best practices from the literature into the adopted sustainable development process without validation. Nevertheless recommendations included proposing a separate study for the implementation of the sustainable development process and a further pilot study into implementing a few key best practices within industry.

Overall this study was successful in helping to identify and validate best practices that were most frequently mentioned by academics and to some extent reflected the existing state of affairs concerning sustainable development and the environment.

ACKNOWLEDGEMENTS

In the name of Allah, the Most Gracious, the Most Merciful.

Endless salutations and benevolent prayers be to Prophet Muhammad (peace and blessing be upon them), all the pure relatives of this exalted Prophet and to all his companions.

I would like to thank my family, my sponsor and my supervisor for maintaining immense patience and perseverance in the completion of this study.

CONTENTS

LIST OF FIGURES

GLOSSARY OF TERMS

EHS	Environment, Health and Safety
BP	Best Practice
SUS-BP	Sustainability Best Practice
NRM	Natural Resource Management

1 INTRODUCTION

1.1 Overview of the Sustainable Development Point of View

Consumption of the world's resources is considered to be at a pace that would leave little for the next generation. Nonetheless progress has been made where offspring born today can expect to live much longer, be more literate than their parents and can expect to gain a higher standard of living. Whilst this offers hope to most, considerable improvement in the way we manage and use our natural resources responsibly and ethically is paramount for survival of future generations than ever before.

The present situation can be summarised as follows (Roberts, 1990):

- The sudden rise in human population in the last 200 years after thousands of years in slow growth has produced non-sustainable demand on the global environmental resources.
- Fossil fuel consumption has increased by 30 times in the same period
- 25% of the world's population gets through 80% of the world resources
- Industrial production has increased by 100 times in the last century.

The natural environment is essential to human activity and is the crucial resource for human society. It is also the 'sink' for unwanted by-products and wastes of the world. Industry, as the key feature of human society processes material from the world's reserve to produce products and services that are increasingly sophisticated leading to environmental impacts.

These environmental impacts such as the effects of pollution from CO^2 resulting from industrial processes leading to global climate change are all pressures on the earth's natural system. This raises further concern that the 'carrying capacity' of the earth is at risk of being exceeded both by the exponential growth in demand for resources and by the harmful effects on resources through human activity. This is summarised in Figure 1-1.

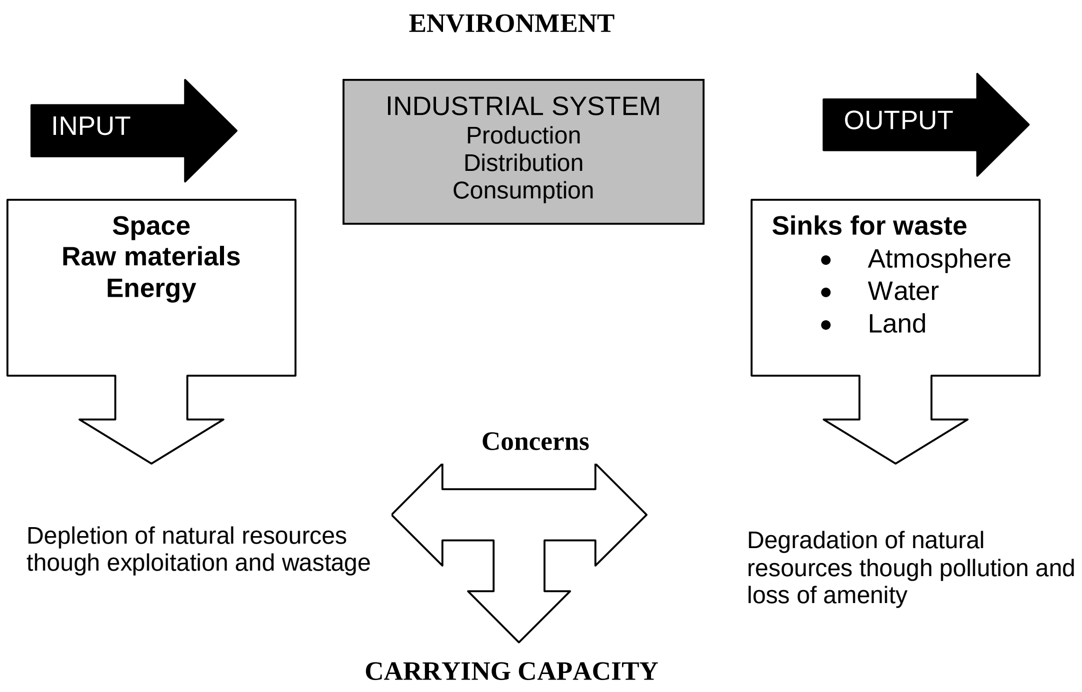


Figure 1-1: Interaction with carrying capacity (source: Hyde et al, 2001)

This approach to the environment has raised the following concerns (IPCC, 2007):

- The warming of global climate now seems unmistakable due to monitoring temperatures of air and oceans and with rising sea levels due to the melting of ice.
- The last 100 years have seen global temperature increase by 0.70°C with global sea levels having risen by 17 centimeters during the 20th century.
- Global greenhouse gas emissions have increased noticeably, with a 70% increase from 1970 to 2004 alone with doubled emissions from the transport and energy sectors.

1.2 Drive to embed best practices

CEMEX has consistently implemented a wide range of initiatives to realize the company's sustainability policies. The company has made efforts that have allowed CEMEX to advance its competitive position, reduce its impacts, and help to improve the quality of life within the communities that it operates in. However, the company acknowledges that it needs to do much more.

The sustainability challenge that CEMEX faces is to maintain its market position, while also ensuring that it operates with minimised environmental impact, generating the greatest possible value for stakeholders. In particular, this MSc individual thesis proposal is focusing to document sustainability best practice (SUS-BP), based on a Sustainability Framework developed in 2008 and is a collaborative venture between CEMEX and the University of Cranfield with a shared vision in finding simpler ways of moving towards sustainability. The principle aim has been to stretch the sustainability boundaries in the construction and mining industry, through the use of a way that takes into account current SUS-BP.

1.3 The Stakeholder: CEMEX

Founded in Mexico in 1905, CEMEX International is one of the three biggest cement manufacturers worldwide and CEMEX UK is one of the United Kingdoms leading provider of building materials. With headquarters in Monterrey of Mexico and European Head Office in Biel, Switzerland, it holds a presence across 50 different countries and operations across 500 locations within the UK. It employs more than 67,000 people worldwide, with 5,000 of them employed within the UK.

With a strong worldwide presence, CEMEX sources indicate figures as of 31st December 2008, yearly production capacity of 96 millions tons of cement, 77 million cubic metres of ready-mix concrete and 240 million tons of aggregate. This is all complimented by 64 cement plants, 2200 ready-mix concrete facilities, 493 aggregate quarries, 253 land distribution centres and 88 marine terminals.

CEMEX is planning to achieve 15% of alternative fuel substitution by 2020 and is studying projects of self-generation and co-production of Electric Energy. CEMEX has committed to reduce 25% of CO^2 emissions per metric ton of cement product, from 1990 baseline by 2015.

CEMEX recognises that the success of its business does not only depend on financial performance or the quality of products and services, but on delivering these in a responsible manner.

That's why it recognizes that climate change is a pressing issue that the world faces. As a responsible corporate citizen, CEMEX assumes its role and has developed a complete approach to reduce its CO^2 emissions worldwide as well as to manage diverse risks and opportunities associated with climate change.

1.4 Project aim and objectives

The aim of this project is to propose a novel way to document all SUS-BP to enable company employees to search, learn and apply such best practices in their daily activities.

The objectives of this project are:

- Understand the previous year's work of SUS-BP through literature review with emphasis on construction and mining sectors.

- Design taxonomy to document SUS-BP suitable for digital documentation.
- Digital documentation of the 11 key individual process areas which will be uploaded in the digital library SMARTBRICKS, currently under development at CEMEX.
- Design a generic methodology (guideline) to support CEMEX implement SUS-BP.

1.5 Thesis structure

This thesis structure is:

Chapter 1: Introduction

Chapter 2: Literature Review

Chapter 3: Research Methodology

Chapter 4: The Sustainability Development Process Cycle Model

Chapter 5: The Taxonomy Design

Chapter 6: Documentation of Processes

Chapter 7: Discussion

Chapter 8: Conclusion

2 LITERATURE REVIEW

2.1 Introduction

This chapter reviews the rapidly growing amount of literature and research on the projects key theme of sustainability. First, the sustainability scene is set with an exploration of sustainability in a wider context followed by a rationale of sustainability from the perspective of the construction and mining industry. Second, the focus is then on some concepts of sustainability, followed by analysis tools and methods for sustainability. Third, follows a study of BP methods in the context of construction and mining using a grid matrix to document and highlight key BP within literature and finally, analyses of regulations that help to drive sustainable construction in Europe.

2.2 Introduction to Sustainable Development

Sustainability can be defined as something which can be maintained at a set level. In ecological terms this means “the amount of which the earth’s resources may be exploited without damaging effect” (Chambers, 1993)

The 3 areas involved in sustainability are represented in Figure 2-1:

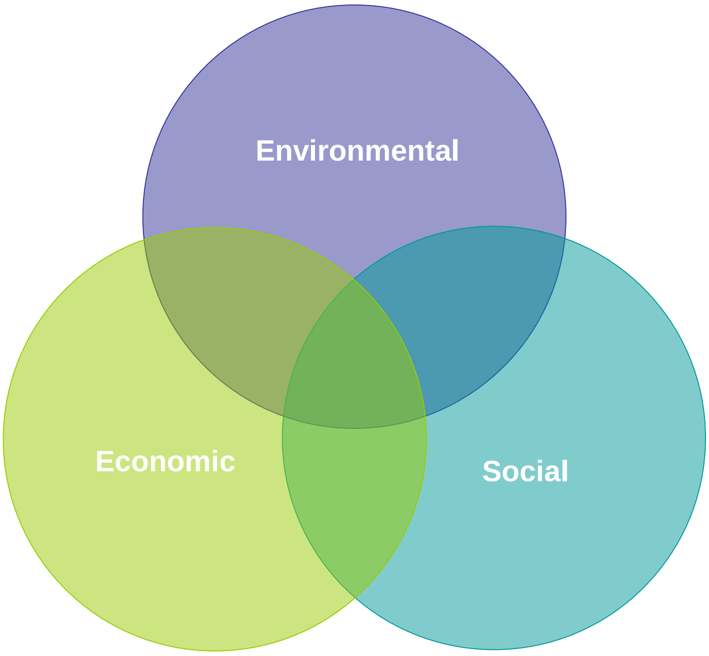


Figure 2-1: The Triple Bottom Line (source: Brady, 2005)

Gaining the right balance between these areas lends support to true sustainability and sustainable development. Vanegas (1995) points to the social component which is concerned with the welfare of humans concerned with the push to raise the standard of living for people who lack the basic needs such as food and water. He further indicates the environmental component as having attention now because deterioration of the environment is driving the current worldwide focus on sustainable development. This requires recognition of the limits of natural resources within the environment. The economic component refers to the social science of production and consumption of goods and services. The barter of goods has a considerable effect since the environment serves as the final source of virgin and waste material. (Vanegas et al, 1995)

The World Commission on Environment and Development fashioned the most widely used definition of sustainable development of “meets the needs of the present without compromising the needs of future generations” (WCED, 1987). Dickie and Howard (2000) defined the contribution of construction to sustainability as sustainable construction and deemed this important as “what we build today will provide for the future generations ability to meet their needs”.

The concept of sustainability is better understood instinctively by current nomadic people who understand the importance of making use of resources given by nature and have gained the value of the knowledge since they are heavily dependent on the planets system for survival. The world commission has observed that modern man has only just begun on the path of discovery to sustainable development, while earlier civilizations have practiced this for centuries. (WCED, 1992)

In this century, the power of technology has enabled humans to transform the environment with excessive exploitation of renewable resources. People have questioned the capability of the planet to support the lifestyle of the developed world. This called for society to embrace the lifestyle with more consideration for the environment and its resources and help alleviate the impact caused by material intensive development.

Mezher and Namani (1999) portion blame for environmental damage with industrial development. Diverse industries all extract resources in the form of materials from the surrounding environment and discharge waste and emissions into the environment. These activities threaten a decline in natural resource reserves and pollution. They considered it essential for industry to take lead in adopting environmentally friendly practices into their policies through the concept of sustainable development, rather than wait for government regulation restrictions to enforce such practices.

Struble & Godfrey (2004) hold responsible human development for the long-term health of the planet, the climate changes resulting from the thinning of the ozone layer and the progressive decline in biodiversity resulting from loss of habitat.

2.3 Concepts of Sustainable Applications

Several researchers have attempted to propose sustainability models in order to help in understanding the inter-related sustainability issues and concerns to address them via specific solutions. The following sections are presenting several of these models.

2.3.1 The Systems Approach

Businesses can be seen as large complex systems containing many subsystems but when considering complex themes such as sustainability it is worth harnessing a "systems mindset" to appreciate their integration and connectivity. This offers the use of a multi-dimensional framework which contains information from different disciplines.

With increasing consumption of natural resources creating large amounts of waste and pollution rendering the planet unable to recover quickly enough from its harmful impacts, increasing population and new technology makes it easier to access more natural resources infinitely.

According to Roberts (1990) in Figure 2-2, this unsustainable technology is the result of more linear rather than cyclic thinking and is at the heart of the shift from unsustainable toward sustainable practices.

Whereas Vanegas (1995) also points out that this unsustainable linear system is what is currently being employed in industry with disregard for constraint of material or energy consumption. This has caused a threefold problem of natural resource reduction; build up of waste and environmental degradation.

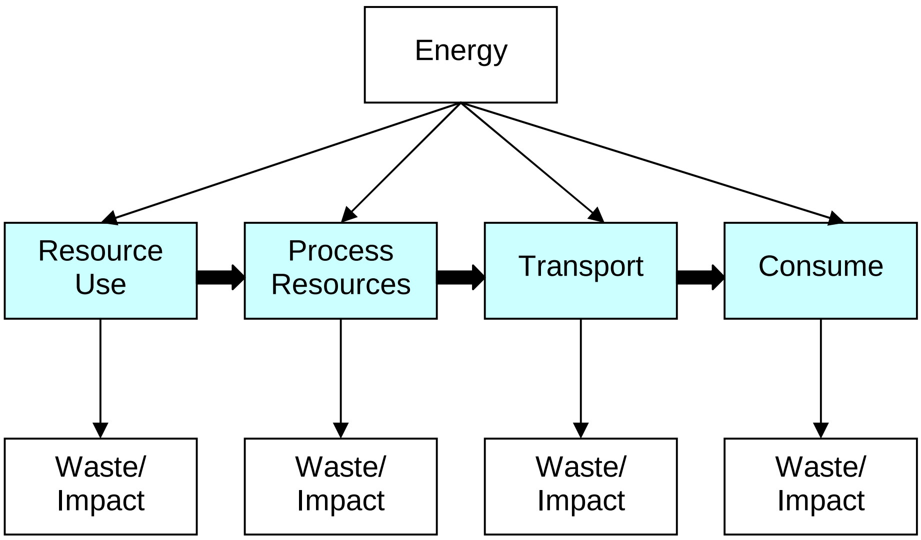


Figure 2-2.Linear Systems Approach (source: Roberts, 1990)

Brady (2005) also highlights this further that the linear process is the legacy of the industrial revolution where the economic and governance systems remained rooted in the linear model of resource use- make, use once and dispose or ‘cradle to grave’ implying a linear process from source to grave. He further iterates that linear patterns differ from natures cyclic flows within which wastes are reused as the resource for ensuing processes.

This is emphasised by Roberts (1990) in Figure 2-3, prescribing this to be adopted as sustainable technologies mimicking natural systems. He suggests that businesses must function like an ecosystem where use, process, transport and consumption must flow as a ‘closed loop’. In this process wastes are minimised and by-products are recycled as recovered resources. Because the degree of impact is kept to a minimum in the system, changes in the environment will be steady allowing the environment to adjust and stay healthy.

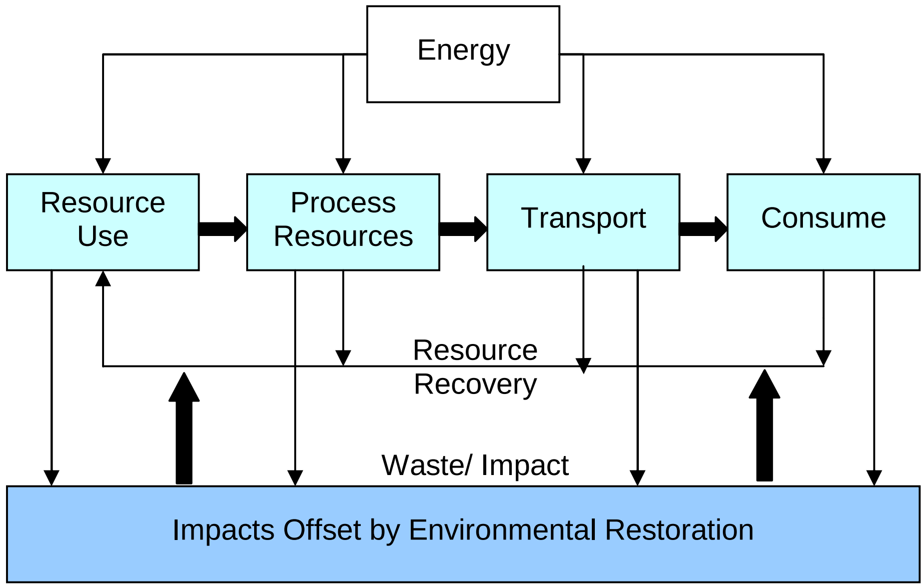


Figure 2-3.Cyclic Sustainable Development Process (source: Roberts 1990)

Instead of a linear process, this model in Figure 2-3 represents a closed cyclical system. This integrated model consists of eleven processes each giving a unique response to a specific sustainability challenge. The framework for sustainable systems presented in Figure 4 is the basis for the sustainability initiative adopted by CEMEX for the purpose of this study.

The framework proposes to implement several criterions for sustainable technology:

- economy in the use of natural resources
- economy in the use of non-renewable energy
- minimal negative impact upon the earths natural environment

Brady (2005) also defines this as 'cradle to cradle' where resources are constantly reintegrated and reused in new productive processes and something industry would need to emulate if it desires to be truly sustainable where "the lifecycle must incorporate fate beyond end-of-life", and "burying or burning does not make things disappear from the Earth's system".

Fiksel (2001) agrees by emphasising the common purpose of this concept, which is to move the company operations from a profit-driven to a value-maximising model. He further states that this move lines up well with the goal of growing worth of increased profits, at the same time as reducing costs, by doing more with less.

2.3.2 <u>The Paradigm Shift</u>

The shift from traditional to sustainable design is proposed by Kibert (1994) as a shift from the traditional focus upon performance, cost and quality to the more dynamic paradigm, incorporating the criteria of minimal consumption and minimal environmental impact suggesting that designers approach their builds as part of their natural environments naturally. This pushes them to take into account the not just the inanimate objects they use to build but also the living objects that operate together as a entire complete system connected together.

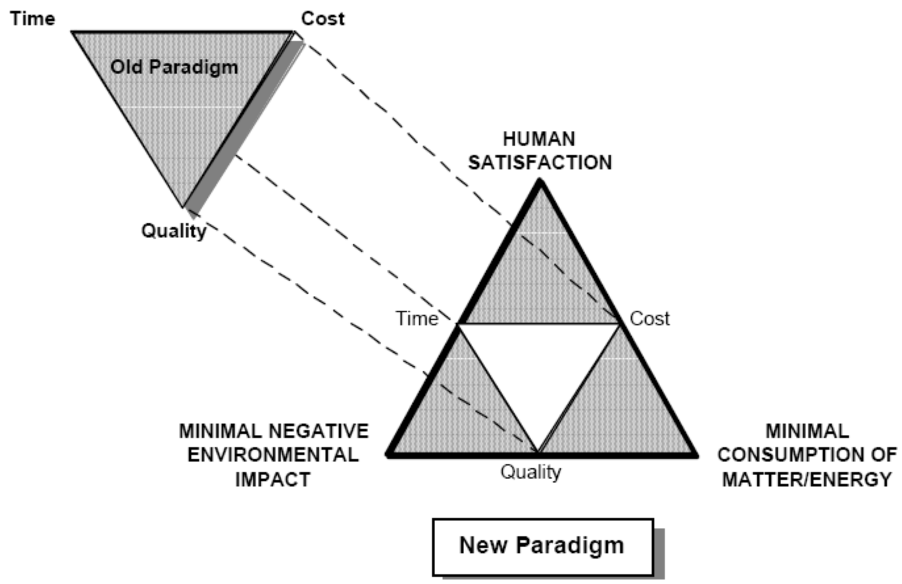


Figure 2-4.Paradigm shift from traditional to sustainable design (source: Kibert 1994)

As Kibert (1994) illustrates in Figure 2-4, the old paradigm is concerned with design and build of facilities irrespective of the wider life cycle considerations of operation and deconstruction that consume matter and energy at the centre and last part of the life cycle.

The significance of this is that changes are easier during design of the facility rather than later during construction whose responsibility falls into the hands of designers. A sooner rather than later shift toward sustainability approach during the design phase is rewarded with a greener construction process that will help current and future generation. (Hill, et al, 1994)

2.4 Tool and Techniques

This section includes having a look tools that are used to implement sustainability at the design and management level.

2.4.1 Life Cycle Assessment (LCA)

Life cycle assessment recognises that environmental impacts have to be considered during the design process and helps to improve the performance of the product across the entire life cycle by changing its design. The purpose of which is to identify ways to minimise the environmental burden. It is defined as a methodical consideration of design with reverence to the environmental objectives of the product life cycle.

In this context Life Cycle Assessment (LCA) provides usefulness for analysing environmental impacts associated with a product, and is the vehicle for further practical application of this information Hyde et al (2001). The figure summarises the flows of energy, materials and emissions accounted for in a standard LCA below.

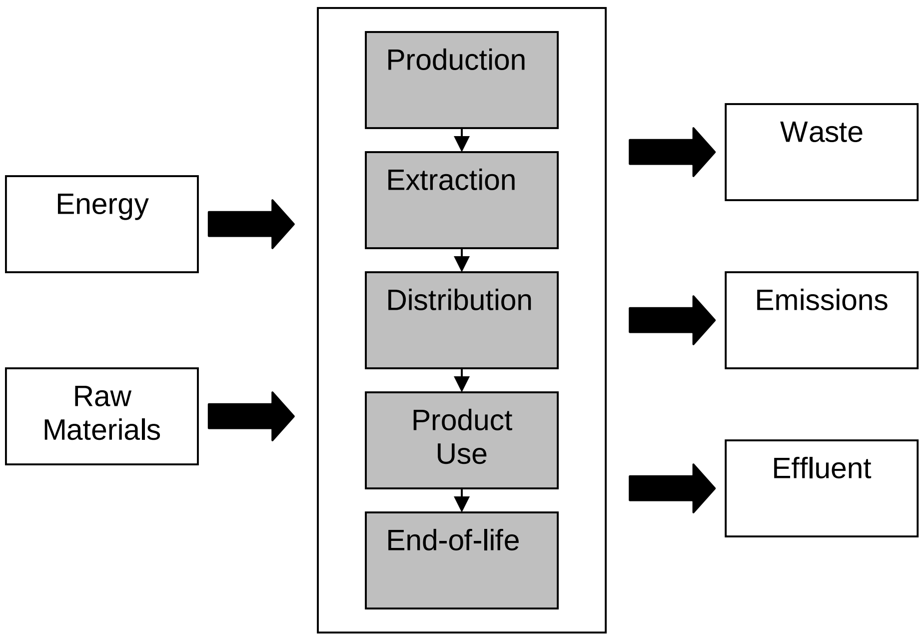


Figure 2-5.Life cycle system stages for a product (source: Hyde et al, 2001)

Hyde et al (2001) argues that LCA can be extremely useful but can be difficult to interpret mainly because it considers the wider picture rather than a particular site, facility or stage of the life cycle stage.

He summarises the key uses of LCA in business:

- It identifies and prioritise the most important environmental aspects in the life cycle for improving performance in the stages most relevant.
- It provides a comparison to environmental performances of other product systems that provide the same function.

2.5 The Best Practice Grid Matrix

2.5.1 Identifying the SUS-BP in construction Literature

This research used the SUS-BP framework developed by Hernando (2008) in order to be the basis to identify their application and adaption in the construction sector. The following six areas of his sustainability framework were validated by project stakeholders who deemed these suitable for the purpose of this study:

1. Energy Efficiency
2. Emissions, Waste and Wastewater
3. General Business Practices
4. Supply Chain Management
5. Health and Safety
6. Standard, Legislation and Regulators

2.5.2 Finding Literature with emphasis on construction and mining industry

This involved finding journals and conference papers where possible, concerning BPs in the construction and mining industry.

Sources of information included trawling through the worldwide web with online databases affiliated with Cranfield University as well as non affiliated sources. Google scholar has been a favourite tool used frequently because of ease of use and quick results. Compared to individual database searches Google often returned hits that covered several databases such as 'Elsevier' or 'Inter-science'.

The following is an example of the criteria used for this initial search (the hits decreased incrementally as the search progressed):

Search 1: "sustainability" AND "construction"

Search 2: "sustainability" AND "construction" AND "mining"

Search 3: "sustainability" AND "construction and mining"

Search 4: "sustainable construction" AND "mining"

Search 5: "sustainable construction" AND “best practice”

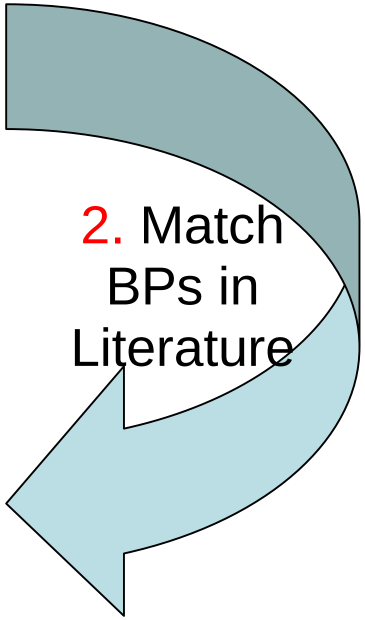
Literature that was broad based, unbiased and not specific to any given BP was a key condition considered for finding information. This was mostly because of limitations posed in the event of literature considered partial toward a particular BP; more general based literature would present less biased information and would cover more of the subject area for the purpose of the literature matrix.

The aim of the literature matrix was to establish the frequency of BPs in the literature. The literature search resulted with 24 documents as shown in Figure 2-6, where BPs were collated from the twenty four papers, whereby examples of which were searched for in the corresponding literature.

Once the BPs had been mapped to the literature list they were drawn down from a list of 140 BPs to a mere 34 BPs. These 34 BPs were the most frequent to be mentioned by authors and academics in their work and further helped to reinforce the most useful BPs to be used in further research of this project. The grid matrix in Figure 2-6 represent BPs that was the most frequently mentioned in literature.

1. BP Framework

Level One	Level Two	Best Practices
Energy Efficiency	Machinery/Process	18
	Facilities	12
	Heat Use/Recovery	9
	Organisational Initiatives	18
Emissions, Waste and Wastewater	Internal Waste	20
	Recycled Material/External Waste	7
	Water Management	6
	Organisational Initiatives	4
	Emissions/Spills	4
General Business Practices	Knowledge Management	2
	Other	10
Supply Chain Management		11
Health and Safety		12
Standards, Legislation & Regulators		7
Total		140



Title	Author	BP1	BP2	BP3	BP4	BP5	BP6
Bio-solids Management	Englande et al 2001	▪	▪				
Cement Manufacture and the Environment	Hendrik et al 2003	▪		▪			
Cement, Concrete & Sustainability	Parrott 2002	▪	▪		▪	▪	
Emergence of a sustainable business community	Fiksel 2001		▪				
Energy Environment Implications of Cement	Das 1997						
Environmental Best Practice in Lebanon	Mezher et al 1999	▪	▪	▪	▪	▪	
European Legislation in the UK	Lindon K A Sear	▪			▪	▪	▪
Evaluating Clean Development Mechanism Projects	Ruth et al Jul-00						
Hearing on Evolution of European Cement Industry	Chandelle May-97						
High-Performance, High-Volume Fly Ash Concrete	Mehta 2001			▪	▪		
How Sustainable is Concrete?	Struble et al 2001	▪	▪			▪	
India's Cement Industry	Schumacher et al 2001	▪					▪
Industrial approaches to "low-CO2" cements	Gartner Jan-04		▪			▪	▪
Policy Modelling for Industrial Energy Use	Worrell et al Nov-02						
Reducing the environmental impact of concrete	Mehta Oct-01	▪				▪	
Sub-study 7: How Innovation Can Help	Fowler Mar-02	▪				▪	
Sustainability of Cement & Concrete Industries	Naik Jan-05		▪	▪	▪	▪	
Sustainability, growth and development	Perrings et al 2000						
Sustainable building technologies	Reddy Oct-04	▪				▪	
Sustainable Material Infrastructure Design	Lepech et al 2005	▪				▪	
The implications of urban sustainability	Curwell et al 1998						
The Quest for Sustainability	Bakshi et al Jun-03						
Tough Dialogue Pays Off	Heimer et al Oct-06						
Use of Fly Ash & Slag in Concrete	Bouzoubaâ et al Jan-05						

Key:

BP1	Reduce Hazardous Waste
BP2	Reuse internal wastes and by-products
BP3	Contract companies to recycle wastes
BP4	Recycle internal wastes
BP5	Use recycled materials
BP6	Use by-products/wastes from other companies

Figure 2-6.Process of mapping construction BP with literature found in this study

The following sub sections present examples of BP from the construction point of view:

2.5.3 *Energy Efficiency:*

Reuse available process energy

This can be mostly acquired through efficient use of energy and energy saving practices where surplus energy can be reused to help further increase production. Parrot (2002) highlights that "renewable energy schemes must be integrated with construction projects where practicable in order to reduce fossil fuel consumption and its environmental effects". He further recommends that companies must "provide support for minimising environmental effects from the operational lifecycle stage of structures, mostly for those linked with fossil energy use".

Gartner (2004) further highlights energy efficiency as a fast change away from primary fuels toward a wide variety of secondary waste fuels in the kiln. He further points out that early oil embargos offered the short-term incentives needed to encourage industry to accept new process technologies that had long-term benefits for industry, for example helping reduce kiln fuel energy usage by 40% for clinker manufacture.

For sustainability Naik (2005) insists on actions that produce energy from use of solar & wind energy; recycle waste energy; and "take responsibility to nature by creating silence for the future generations by minimising maintenance."

Cogeneration

Ruth et al, 2000 highlight the importance of cogeneration for controlling carbon content for the grinding stage with electricity is the energy. The process cannot utilise other fuels unless the power plant is located onsite.

According to Schumacher et al (1999) because of frequent power cuts that affect plant operations, the cement industry has already begun installing power generating units based on cogeneration, leading to considerable savings in energy use and costs. He further highlights that this is an attractive scheme for the cement industry and its waste heat from the high temperature processes of cement production is right for. He points out cogeneration systems were not adopted because the of a lack of vital technology, high installation and maintenance costs did not permit companies from installing cogeneration units.

Worrell et al (2002) states that several technical and market factors prevent further use of cogeneration, and that 80% of the potential capacity is still unused. Worrell further highlights the most potential for cogeneration is to be found in less energy intense manufacturing sectors.

Economically Viable Renewable Energies

Mezher et al (1999) recognises that energy consumption constitutes a large proportion of total production costs due to heavy reliance on private generators and because the government supplied electricity is being more expensive.

Worrell et al (2002) defines new and renewable energy to include wind, solar, wave and tidal energy. He emphasises that over the next 20 years, use of renewable energy is predicted to fall from 8% in 1999 to 6.8 percent in 2020 because of a push to use commercial fuel due to socioeconomic development.

According to Placet et al (2002) cement plants have experimented with using renewable energy to supplement electricity from conventional plants.

Reddy, (2004) strongly emphasises that in order to continue construction activity, further study of renewable energy sources and technologies will occur.

2.5.4 Emissions, Waste and Wastewater:

Reduce Hazardous Waste

According to Englande et al (2001), "waste treatment facility design and operation has to be in line with better resource use and recovery by the production of non toxic waste". Adding to this, he also states that ash from the seven sewage plants in the suburbs of Tokyo is supplied for the manufacture of Portland cement where dried dewatered sludge cake is utilised as raw material and fuel for Portland cement. He concluded that if successful, this process could utilise all sludge generated in Japan, where a sludge drier, not an incinerator, would only be needed to help reduce the CO^2 release problem.

According to Hendrik et al (2003), reduction of emissions can be further achieved by plant improvement using more efficient technologies and by switching to alternatives to fossil fuel that have lower carbon content.

Parrot (2002) also supports this as being derived largely from improvements in cement manufacture that have helped decrease emissions of nitrogen oxide, carbon monoxide, sulphur dioxide and heavy metals from the period of 1994 to 2001.

This is supported by Sear (2004) who states that waste management strategies must be aimed at preventing waste generation and further help to minimise its impact. He adds that where this is not achievable, waste matter ought to be used for energy or recycled leaving the last option of safe incineration.

Placet et al (2002) highlights the use by industry of waste sludge as material for cement manufacture. He directs toward a research project with Tokyo

Metropolitan Government where CFCs are injected into a cement plant rotary kiln resulting in their successful elimination. He further specifies how this is achieved at high temperatures of about 1450 °C, where CFCs are decomposed entirely into hydrochloric and hydrofluoric acids, forming non-hazardous clinker materials. This is known to destroy approximately 99.99% of CFCs and removes the need for the kiln's flue gas to be treated.

Reuse Internal Wastes and By-products

Englande et al (2001) demonstrates that until recently, additional innovative processes have been developed for reusing wastes. Some of these include heat drying and alkaline stabilization with in-vessel composting. He emphasises that these produce stabilized products that are feasible for reuse and affordable.

Fiksel, (2001) argues that research in green chemistry has been linked to areas such as increasing the eco-efficiency of processes in industry through regeneration of feedstock from waste by-products.

Mezher et al (1999) further argues that the single, most important factor demonstrating the environmental responsiveness of manufacturers is how they handle by-products, where almost three-quarters of the companies surveyed recycle their solid waste either in-house or through specialized recycling companies. Nevertheless, he points that some companies are still dumping their solid waste carelessly.

The demolition process of concrete is done through brute force involving controlled blasting or hammering. The waste produced by demolition of a concrete structure includes dust, powder, and fragments of concrete. Dust, unused concrete, and wash water contaminated with concrete are the major waste, which, to some extent, can be reclaimed or reused. (Struble et al, 2001)

Placet et al (2002) recommends that for achieving larger quantities of high-quality cement, adding waste steel slag to cement mix helps to produce less pollution. This by-product of steel production known as 'slag' generally reused in road construction.

Use Recycled Materials

Mezher et al 1999) argues from his study of an investigation of raw materials used by company's shows that they still use hazardous or toxic materials whereas paper, pipe, and electrical cable companies use recycled or renewable materials as their primary material. He further advises that firms should go beyond mere compliance with government regulation and should actively promote environmental conservation, through using material that reduces environmental impact.

This is further held by Placet et al, (2002) who has highlighted that the shortage of resources such as land in the Netherlands has resulted in regulations for demolition waste. He further believes that sustainable constructions have a small impact on the environment since “they use green materials, which have low energy costs, high durability, low maintenance requirements, and contain a large proportion of recycled materials”.

Naik (2005) adds to this by stating that due to stricter environmental regulations, the disposal costs for by-products are rapidly escalating. He emphasises that recycling and creating sustainable construction designs not only contributes to reduced disposal costs, but also aids in the conservation of natural resources.

However, Reddy (2004) agrees that another aspect of efficient use of materials and resources is the recycling and reuse of demolished wastes from building is. He argues that the recycling of this waste is still not done in an organised manner. This is mostly because of limitations in India of research in sustainable building technology.

2.5.5 General Business Practices:

Climate Change Awareness Program

To enable businesses to become more aware of climate change, Fiksel (2001) argues that industry has identified that long-term success depends not just on economic performance, but equally or more on social and environmental performance. Stakeholders are now confronting concerns over sustainability issues. This is advocated by Fiksel (2001) that companies are addressing growing public awareness of sustainability, increasing their competitive advantage by encouraging changing expectations of new technologies. This is further supported by Placet et al (2002) stating that this is achieved by educating employees about why both innovation and sustainability are essential in helping face the business challenges involved.

Knowledge Sharing

Placet et al (2002) strongly stresses that effort should involve organised systems to encourage networking within the company for sharing information and problem solving. This is accomplished by sharing innovative ideas through cross-company meetings and other knowledge management systems. He further stresses that rewards are useful to help encourage ideas and progress cooperation. Naik (2005) and Worrell et al (2002) also call attention that constant improvement should be sought by the sharing of knowledge.

2.5.6 Supply Chain Management:

To encourage suppliers to be more sustainable and ensure that long-term contractors comply with the same sustainability policies as the company, Hendrik et al, (2003) and Placet et al (2002) put emphasis on forming partnerships with suppliers to promote research & development focused on sustainability, where these partnerships help identify useful product, service and process innovations further stressing that strategy innovations are becoming more and more important. Placet et al (2002) and Ruth et al (2000) puts across the challenges confronted by suppliers that supply cement plant technology and how partnering with their customers the cement companies helps to advance the energy efficiency of cement production.

2.5.7 Health & Safety:

Programmes that foster healthy lifestyles was put across by Placet et al (2002) where many companies monitor worker health and safety, provide training associated with sustainability. Fiksel (2001) also strongly stresses that by investing in an up to date workplace incorporating and ecologically harmonious design, the company can expect to improve health and safety, productivity employee morale.

2.5.8 Standards, Legislation, Regulators:

By creating standards as a company to have a global approach worldwide, Parrot (2002) calls to attention information that is required for the role that cement industry plays in improving sustainability at world, national and local levels. He stresses how this needs synchronised action such as benchmarking to highlight areas of potential improvement. (Parrot, 2002)

Hendrik (2003) also stresses that industry benchmarking by establishing key performance indicators is supported by consensus standards such as the Global Reporting Initiative. However, Worrel et al (2002) directs to various methods that exist to estimate the potential for energy efficiency. One such method that has received worldwide attention is the use of benchmarks to assess the performance of an industrial energy user. By working closely with local authorities to obtain benefits, businesses ensure that in decision making there is ample local community involvement. This helps determine how new builds will impact human development through the use of citizen's advisory committees and action groups. These are designed to help develop understanding of the effects of using local materials and local resources. (Curwell, 1998)

2.6 Environmental Legislation and Regulation

European sustainable initiatives have been influenced by two major global events. Ways of achieving sustainable development were discussed during the 1992 Earth Summit (UN Conference on Environment and Development).This resulted in an agreed action plan consisting of 27 principles, known as Agenda 21. This was transmitted to all countries to develop their own individual national sustainable development strategies.

As far back as 1999, an agreement was made under the UN Framework Convention on Climate Change by The Kyoto Protocol setting worldwide and European targets for the reduction by 12% of greenhouse gas emissions below 1999 levels by 2010.

The policy of the UK's Department of Trade and Industry Sustainable Development Programme (2004) for sustainable development is set against global initiatives of the Earth Summit and the Kyoto Protocol.

The Royal Institute of Chartered Surveyors (RICS) estimates that the construction industry produces 40% of all UK. The introduction of the UK Landfill Tax was established to help reduce waste, resulting with most contractors having waste management policies in place (RICS, 2005).

2.7 Closing Remarks

Roberts (1990) in Figure 2-3 provided a model of the sustainable development process to be adopted in later chapters.

The literature matrix provided use as a tool for organising and extracting the relevant BP from a vast amount of available literature.

Areas that were of interest were emissions, waste, waste and wastewater that provided the greatest frequency of 35%, followed by standards and energy earning the frequency of 20% each respectively. General BP accounted for 16%, supply chain 10% and finally health and safety a lowly 2%.

3 RESEARCH METHODOLOGY

The methods that have been used to collect the information needed for this project are explained in the following sections that outline what research strategy was used and how the research was conducted.

3.1 The LEAD Framework

The research methodology applied in this project is broken into the four different processes from the LEAD framework (LEARN, ENERGISE, APPLY and DIFFUSE) applied in CEMEX. These were proved useful in collaborative projects with external partners (Flores 2008).

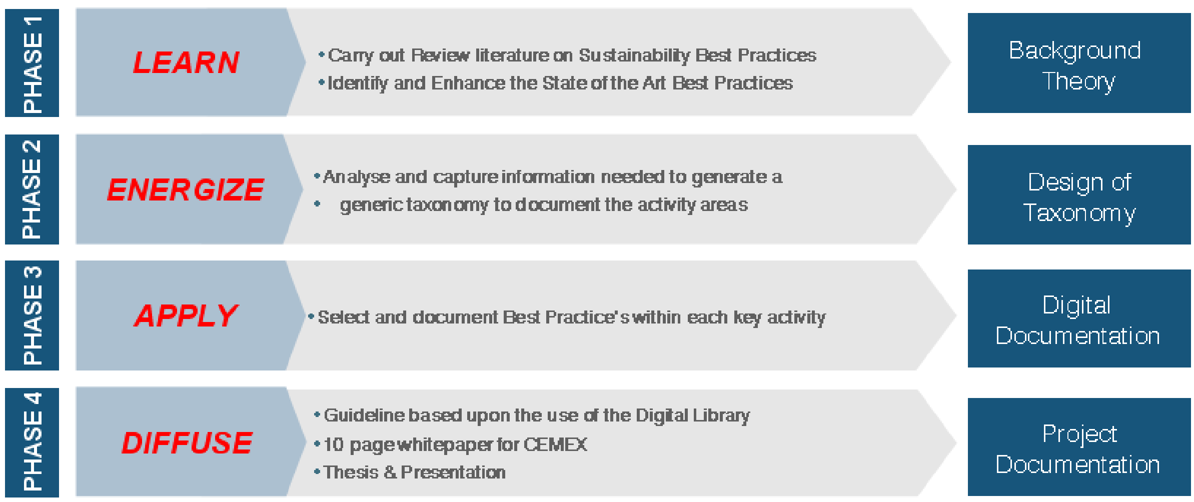


Figure 5: The LEAD methodology, developed in CEMEX research group

3.2 The Research Programme

The methodology of the project consists of the following steps:

1.1.1 Phase 1: LEARN Background Theory

1. Enhance the state of the art of the SUS-BP through extensive literature review. This should be based on journal and conference papers. (Presented in Chapter 2)

2. Adapt and modify the 'Construction Sustainability Development Process' (Roberts, 1990) to be the base for developing the digital sustainability library.

1.1.2 Phase 2: ENERGIZE Design of Taxonomy

3. Develop and understand taxonomy design through literature review.

4. Design a generic taxonomy template to document the key Processes of the Sustainable Construction Development Process Model.

1.1.3 *Phase 3: APPLY Digital Documentation*

5. Within each key process, up to 5 SUS-BP will be selected in order to populate the process for sustainability information.

6. Develop a guideline to support CEMEX implement SUS-BP based upon the use of the Digital Library.

1.1.4 *Phase 4: DIFFUSE Project Documentation*

7. Creation of a flyer and a client brief

8. Write a 10 page whitepaper for CEMEX (Executive Summary)

9. Design a Poster

10. Write a Thesis

4 PHASE 1: BACKGROUND THEORY

Since extensive literature review based on journal and conference papers was conducted in Chapter 2, the remaining part of this phase involves firstly describing the method for the adaption and modification of the 'Cyclic Sustainable Development Process' from Roberts (1994). This was developed into the proposed 'Construction Sustainability Development Process Model' for developing the digital sustainability library, as described in the execution of Phase 1.

4.1 The Sustainability Development Process Cycle Model

The purpose is to generically adopt the key activities that were proposed by Roberts (1994) and integrate these to best suit the plans of construction companies. This involved adding new subsystems that are deemed appropriate. What this does not necessarily imply is changing the definitions of the 4 main key subsystems or removing them, because this would certainly risks undermining Robert's theme and miss the spirit of his message. For the purpose of this study, attempting to literally superimpose the structure of Robert's process would be required onto the BP framework of the literature review and adding any necessary key subsystem so as to encase this.

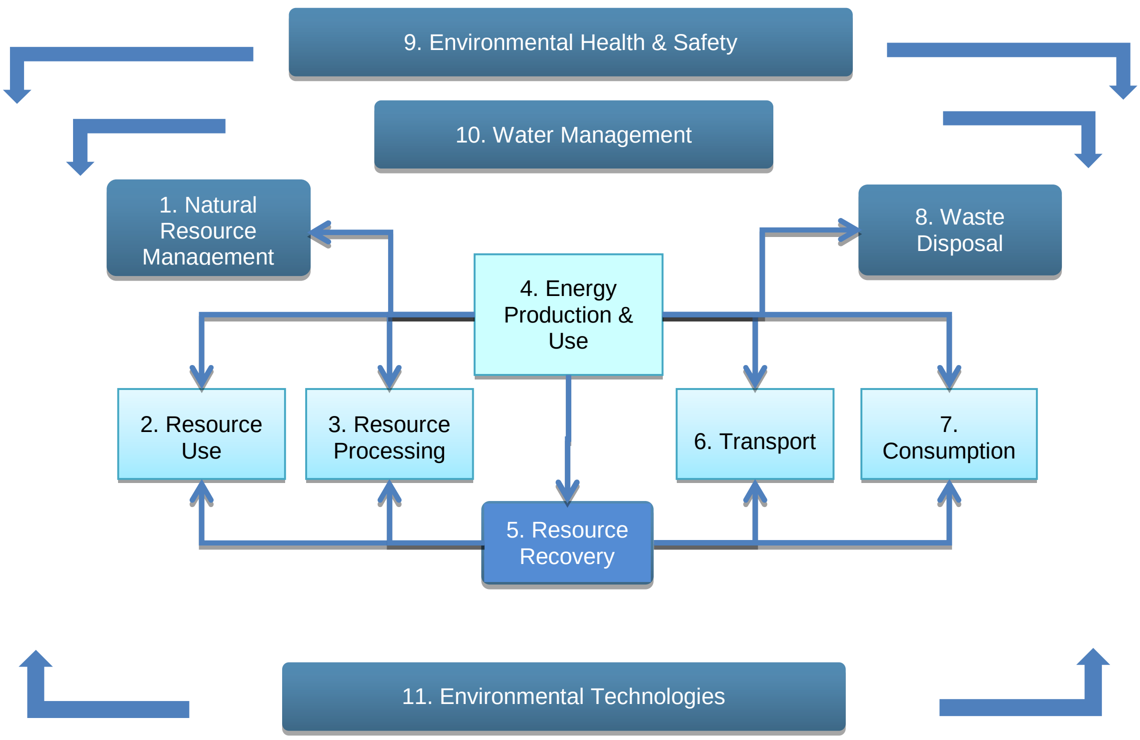


Figure 6.The Sustainability Development Process Cycle Model

4.2 Adaption of the Sustainable Development Process Cycle Model

The process names were changed appropriately to help clearly distinguish one from the other. The numbering criteria chosen for the processes in the Sustainable Development Process Cycle Model was deliberately followed using a hypothetical flow of material from the primary 'resource use' process 2, then process 3, 4, 5, and 6 through to process 7 of 'consumption' before flowing onwards to the outer processes. This is highlighted by the colour co-ordinations of the processes in Figure 4-6.

For the purpose of creating digital documentation of these individual processes that would also contain BPs, the following principles were applied:

- Adopt and rename the process without changing the principle function that it proposes to do;
- Establish the definition and role of each process in the wider context of company's business processes;
- Understand how it interacts with other processes;
- As first choice, place the high rated BPs from the literature matrix against the appropriately defined processes;
- Where complete information is lacking concerning these BPs, find alternatively similar BPs from other sources.

This literally involved placing definitions against the key processes of the construction sustainability development process model.

Environmental Health and Safety (EHS) and Water Management were added as new processes into this model to support the overall organisational business processes and were considered important by stakeholders as central to the function of business processes within the construction industry and further assist the adoption of BP. These processes encompassed other processes in the SDPC model in similar fashion to Environmental Technologies by integrating these integral key functions throughout all of their functionalities.

Process 1: Natural Resource Management (NRM) monitors and controls non-renewable resources to prevent their total depletion by effectively tackling the need to manage the exploitation and use of primary resources. This is why this is indicated by an arrow input into the "Resource Use" process in figure 4-6 and is appropriately numbered as 1. This is the starting point from which resources are managed effectively before any further input begins into the 'Resource Use' process. This further directs the requirement to manage resources here in such a way that supply will always exceed demand continuously. Environmental impacts are minimised and the waste stream is also managed with Waste Disposal where NRM uses technological aspects of Environmental Technologies to help achieve these objectives.

The following BPs were considered most suitable for this process:

1. Create standards as a company to have a global approach worldwide:- changed to ISO 14001;
2. Long-term contractors comply with the same sustainability policies as the company:- modified with a further addition of a Sustainable Construction and Site Waste Management Plan (SWMP);
3. Lean Construction.

Process 2: Resource Use is defined as tackling the need to effectively and responsibly minimise the use of limited resources and to create alternative materials where practical. This was emphasised by Roberts (1990) who states that there is a need to minimise the use of resources that are in finite supply and use substitute products where feasible. More or so this is considered as exploiting virgin resources for further use downstream by other functions. Undoubtedly NRM has a direct input with this process as does the Environmental Technologies and Resource Recovery processes. Its main output is to Resource Processing that modifies material that flows out from this process.

The following BPs were considered most suitable for this process:

1. Use of biodegradable substitute products;
2. Minimise land disturbance in-situ leaching;
3. Mine backfill;
4. Semi-open cut mining.

Process 3: Resource Processing is concerned with the efficient use of energy and water in industrial processes; decreasing waste and creating resource efficiency. This process is mostly concerned with modifying resources into products and services. Inputs from Environmental Technologies and Resource Recovery lend this process importance since this process is mostly concerned mainly with modifying virgin resources into products and service to be passed further downstream. There is a limited input of primary material from Resource Use due to a greater dependence on recycled material flowing back from Resource Recovery This shows this process strives to reduce environmental impacts and the heart of its operations is sustainable technology.

The following BPs were considered most suitable for this process:

1. Co-production of electricity and cement;
2. reuse of waste material in the rehabilitation of mines sites;

3. improving the mixing so that by-products in the reaction are minimised; altered by adding pozzolans and admixtures
4. Bio-solids injection

Process 4: Energy Production & Use is concerned with maintaining economic growth whilst providing secure energy and environmental protection. The purpose of this process is to use less environmentally harmful sources of energy while at the same time reducing the net energy consumption through better and more efficient technology. This is where alternative and eco-friendly energy sources such as solar and wind energy are favoured more in this model since this compliments other processes in their function. This process inputs into all the other entire processes and is the fuel for their operation.

Resource Recovery feeds back into this process because key activities allow recycled materials for example to be reused as potential fuel. This also feeds to the waste and environmental impact streams for the reason that some likely waste is produced and is likely to have some impact. This is offset by Environmental Technologies because this process is heavily dependent upon sustainable technology for enable efficient energy production and usage.

The following BPs were considered most suitable for this process:

1. Cogeneration or 'combined heat and power';
2. Economically viable renewable energies;
3. Solar energy;
4. Wind energy;
5. Waste derived fuels.

Process 5: Resource Recovery is concerned with the collection and separation of waste materials for processing into new forms. This can potentially involve the use of waste from other industries or companies and utilising this to be processed into other products or services. This process is fundamental to the correct operation of all the other processes except NRM. Needless to say this process is very similar in functionality to resource processing and in reality may very well use the same facilities. This inputs material or resources directly backwards into Resource Use, Resource Processing and Energy Production demonstrating that this one process is the feedback mechanism by which the flow is redirected back to these. This would also add to reducing the total quantity of waste that needs disposal.

The following BPs were considered most suitable for this process:

1. Use by-products or waste from other companies – changed to 'utilisation of petrochemical waste reuse in cement kilns';

2. Use of waste steel slag in cement;

3. Re-use internal wastes and by-products – changed to ‘Utilisation of cement kiln dust and ash in the reclamation of mines’;

4. Recycled concrete aggregate for cement manufacture.

Process 6: Transport is concerned with providing economic connections with the access needs of individuals, companies and society to be met safely and in a manner consistent with maintaining human health and the environment. This takes an input from Environmental Technologies and Resource Processing as the logical flow of products or services passes this way and in similarity to this function, Transport takes feedback from Resource Recovery.

The following BP were considered most suitable for this process:

1. Retrofit company vehicles with hybrid technology;

2. Foster Public Transport Use;

3. Use video Conference rather than life meetings.

Process 7: Consumption involves the need for taking a life-cycle viewpoint in consumer decision-making, minimising waste, pollution and resource use. The linear process ends at Consumption with the flow of products and services that were generated across all of the processes. The two outputs from this system of increased environmental impact and increased waste are at the heart of concern with regards to sustainability.

The following BP were considered most suitable for this process:

1. Sewage sludge used in the manufacture of eco-cement- found useful for minimising resource use and waste;

2. Making rammed earth walls using soil and cement;

3. Re-using materials, buildings and equipment;

4. Use of Waste Tires as alternative energy in the rotary kiln;

Process 8: Waste Disposal is concerned with the gathering, moving, processing, recycling and disposal of waste and recognises that certain quantity of waste is to be expected and is considered unavoidable. The key here is to understand that this process requires ways of disposal that will not harm the environment but will compliment recovery. All other processes input into this and the only other output from this is the environmental impact it may cause.

The following BP were considered most suitable for this process:

1. Reduce hazardous waste by injecting chlorofluorocarbon gases (CFC) into cement kilns;

2. Sell internal waste to other companies;

3. Contract companies to recycle or extract waste from other companies.

Process 9: Environmental Health & Safety (EHS) is concerned with preventing people from being harmed and providing a satisfactory safe working environment. This process produces no waste or environmental impact within this model but would take inputs from Environmental Technologies and NRM processes. However output occurs with all the 4 basic processes of Resource Use, Resource Processing, Transport and Consumption.

The following BPs were considered most suitable for this process:

1. EHS Audit Achievement Certification Programme;

2. Lead Safe Programme;

3. Programmes that foster healthy lifestyles.

Process 10: Water Management involves the need to manage renewable and non-renewable water resources. Functionality of this process takes inputs from NRM, Energy Production and Use, Resource Recovery and Environmental Technologies. Output from this enters Waste Disposal and all the 4 basic processes of Resource Use, Resource Processing, Transport and Consumption. This process would produce waste and environmental impact but this would be offset by Resource Recovery and Environmental Technologies that would feedback.

The following BPs were considered most suitable for this process:

1. Rainwater harvesting;

2. Water Reuse;

3. Reduction of wastewater volumes through Closed Loop Cooling Systems;

4. Reduction of water use.

Process 11: Environmental Technologies addresses the application of technology to help conserve the natural environment and its resources, and to limit the negative effects of human involvement. The purpose is to lessen environmental impacts before they occur through preservation and prevention. This takes into consideration damage done previously to the environment and proposes recovery action as supplement to this. This process integrates this into every process within this model

The following BP was considered most suitable for this process:

1. Grey water Systems

5 PHASE 2: DESIGN OF TAXONOMY

The purpose of this phase was to develop a generic taxonomy that could capture the relevant BP by way of identifying, documenting, sharing, adapting, for reuse or implementation within an organisation or across the supply chain.

5.1 Phase 2 method

By understanding and developing taxonomy design through literature review, the intended purpose is to understand in the course of academic literature, how a 'generic' template can be used across the supply chain from end to end business processes. To appreciate this, an understanding of how to manage information of BP was needed. In the supply chain, where it is considered essential to meet customer requirements, a digital library is considered useful to help disseminate documented BP, facilitating workers to implement these in their daily work lives.

The factors that enabled development of the taxonomy (Flores et al, 2008):

What: this is specifying the nature and identity of the BP through its definition;

Why: the cause or intention underlying the BP;

Role: the actions and activities assigned to, required or expected of a BP;

Limitations: conditions and restrictions that limit implementation of the BP;

Benefits: economical, social or environmental advantages of the implementation of the BP.

5.2 Execution of the Phase 2 method

A challenge was to make it user friendly allowing user access to the information without difficulty.

The design of the taxonomy was based on incorporating 5 simple principles:

- Creating a general template by using light colours making the text easy to read by anyone;
- Designing the different sections in order to make them easily identifiable and usable;
- Defining the standard fonts to be distinct;
- Seeking logos to match and illustrate the content, catching the users attention without distraction and reinforcing the colour code effect;
- Section numbering has been arranged in such a way so not to confuse the user and provide easy location within the documentation.

1.1 Definition of Process
Description of the process and its relevance within the supply chain, including its purpose
1.2 Role of Process
The key factors of the process, those elements that help the process to achieve its objectives and optimal performance
1.3 Best Practice(s) related to Process
Description and meaning of examples of best practices, its relevance and attached case studies where possible
1.4 Implementation Methodology
The manner of which to apply the best practice(s)
1.5 Benefits of the Best Practice(s) for the Process
Advantages of the deployment, control and correct handling of the best practice(s)
1.6 Limitations of the Application of the Best Practice(s)
Restrictions and conditions for the implementation and of the best practice(s)
References
Sources for the best practice(s) including journals and conference papers

Figure 5-1.Construction Best Practice Taxonomy

It must be pointed out that documentation of each process would contain information on more than one BP; therefore sharing of each of these subsections was arranged in numbering by the same order as the first subsection. For example, Process 10, 10.1 Definition of Process, 10.2 Role of Process, and 10.3 BP related to process, 10.3.1 Energy Efficiency BP, and so on.

The different fields are further explained:

1. **1.1 Definition of Process:** The purpose of this field to provides a simple explanation of the process and the area of sustainability to which this specifically belongs to. This definition may only be subject to a single interpretation of the process and to help avoid confusion.

2. **1.2 Role of Process:** This field provides more detail concerning the process in the wider context of sustainability in relation to other processes, and more specifically the essentials that help this achieve its objective and fulfil its purpose.

3. **1.3 BP(s) related to process:** Here the emphasis is on providing descriptive text for the definitions of BPs in more detail. This defines the scope of the BP in relation to the process and the idea at this point is that more than one BP can be placed here, provided the numbering convention is followed correctly. Insertion of graphs, tables or pictures is generally to be avoided in this field.

4. **1.4 Implementation methodology:** Similar to 1.3, this field permits a detailed description of the method of application of the BP in industry is provided here and objects such as pictures may be placed here to aid this. The section numbering applies and is essential in maintaining a good structure to be followed.

5. **1.5 Benefits of BP(s) for the process:** This section provides a short bullet form description signifying the estimated benefits in the event of successful implementation of the BP(s) according to the particular aspect of sustainability.

6. **1.6 Limitations of the application of the BP(s):** This section provides an account of the risks, limits or conditions that restrict or prevent full implementation of the BP(s).

7. **1.7 References:** The preference given here if for journals or conference papers, but this field has scope for books, internet or other adequate sources. By way of example in Chapter 6, references are entered in the Harvard or Oxford format to aid this study, but this will be subjective by whoever adopts this template.

6 PHASE 3: DIGITAL DOCUMENTATION OF BEST PRACTICES

The purpose of this chapter is to demonstrate the application of populating sections of the taxonomy with relevant BPs. This is followed by a guideline to support CEMEX implement SUS-BP based upon the use of their digital Library.

6.1 Phase 3 method

The key findings from earlier stages are used to populate the taxonomy under the appropriate key process.

This involved researching and understanding the process and the associated BP further by finding complete examples through the literature. If this was deemed insufficient then further material was sought to help credibly populate the taxonomy, keeping in mind that even at this stage if material relevant to the process heading under construction and mining was not found then the best BP was abandoned in favour of a search for a similar example.

6.2 Execution of the Phase 3 method

6.2.1 Process 1: Library for Natural Resource Management (NRM)

1.1 Definition of NRM
NRM addresses the need to successfully manage the use of natural resources in a way that guarantees that supply will always exceed demand, ensuring the quality of life for present and future generations.
1.2 Role of NRM
The objective is to improve human life quality involving the use effective and administration of resources. It is based on the values of ecology where distributes the cost and benefit of development activities using conflict resolution and systems analysis and conflict resolution throughout the impacted environment seeking to protect the processes of development from natural and man-made hazards
1.3 Best Practices related to NRM
1.3.1 Contractors comply with the same sustainability policies as the company with a sustainable construction and site waste management plan (SWMP) A sustainable construction and site waste management plan is a scheme that sets out to objectively measure and reduce the carbon footprint of activities within the construction sector. This works as a "living" plan that is produced on a construction site detailing the amount and type of waste that it is going to be produced, detailing how it will be recycled or disposed of.

1.3.2 ISO 14001

The aim of the standard is to minimise the pollution and waste a business produces. ISO 14000 environmental standards exist to help organizations understand how their operations can affect the environment.

1.3.2 Lean Construction

Lean Construction is a new way to help design and build facilities. Applied to construction, changing the way work is completed right through the delivery process. Lean Construction works with the principles of maximising value and minimising waste.

Source: www.leanconstruction.org

1.4 Implementation Methodology

1.4.1 Implementing a sustainable construction and site waste management plan (SWMP)

1. This has to be prepared as early as possible in the project plan before starting and will require updating regularly. A principal contractor is appointed by the client to guarantee that detailed SWMPs can be prepared by the following process.
2. Start putting in places the necessary training and administrative systems.
3. For each project establish individual responsibility for grounding and functioning of the SWMP.
4. Set time apart to arrange and put in order the SWMP.
5. Identify contractors producing major waste and carry out systematic evaluation to identify different types of waste that will be produced.
6. Identify the waste management options.
7. Insert conditions for responsibility in contracts.
8. Establish plans to guarantee compliance and how violations should be dealt with.

1.4.2 Implementing ISO 14001

There are key steps that every company implementing an EMS will need to consider:

9. Gain assurance and support of superior managers
10. Consider training from training courses
11. Review the option of independent consultancy on the best method to grasp and realise the environmental management system.
12. Choose a 3rd party registrar - who measures the efficiency of the environmental management system, and issues certification if standards are met.
13. Develop an Environmental Policy - this will state the commitment to compliance with standards, legislation and the avoidance of waste.
14. check and construct objectives to help identify the rudiments of the

business that effect the environment

15. The implementation phase should consist of resources for personnel that should be provided with clear defined roles within the organization.
16. Gain registration by a two step process, including a document review and site visitation.
17. Continuous assessment required

Source: http://emea.bsiglobal.com

1.4.3 Method of implementing lean construction

18. Select willing partners and suppliers eager to adopt lean methods
19. Engage downstream with upstream processes and vice-versa
20. Define project scope and budget
21. Explore methods for practising the lean ideal
22. Exercise production control in agreement with lean principles
23. Build quality into projects by placing responsibility on designers and engineers

Source: www.leanforumbygg.se

1.5 Benefits of the Best Practice for NRM

1.5.1 Benefits of Implementing a sustainable construction and site waste management plan (SWMP)

- Elimination of hidden wastes
- Reduced pressure on landfill sites
- Increased efficiency of the supply chain
- Improved links with key suppliers

1.5.2 Benefits of implementing ISO 14001

- Reduced cost of the product due to the less quantity of materials and energy needed for manufacturing
- Increased revenue from recycling manufacturing waste.
- Improved employee health and safety, thus improving productivity
- Reduced insurance claims helping reducing the cost settlements.

1.5.3 Benefits of lean construction

- The facility and its delivery process better able to support customer service
- Maximised value and to reduced waste at project delivery level.
- Efforts to run and improve performance are intended at improving project lifecycle
- The performance of the planning and control system is measured and improved.
- Lean construction is valuable on complicated and short projects
- Elimination of waste and inventory

Source: www.leanconstruction.org

1.6 Limitations of the Application of the Best Practices
1.6.1 Conditions for implementing a sustainable construction and site waste management plan (SWMP) • The client must enable the principal contractor to comply with rules and regulations. • The main contractor must ensure co-ordination between contractors • Measures are required to stop the illegal disposal of waste from the facility **1.6.2 Limitations for implementing ISO 14000** • ISO certification is entirely voluntary. • A business that does not partake in the program will not be encouraged to observe environmental laws • ISO 14001 might not remove a businesses need to obey environmental management standards adopted by other businesses. • The quality of the audit depends upon the integrity of the person performing the audit. **1.6.3 Limitations for implementing lean construction** • lack of willingness to share and learn • resistance to change • threats apparent in change of status and redistribution of authority
1.7 References
1.7.3 Internet • emea.bsiglobal.com • www.pinsentmasons.com • www.leanconstruction.org • www.leanforumbygg.se

6.2.2 Process 10: Water Management

10.1 Definition of Water Management
Water Management is concerned with the need to manage water resources while taking into consideration the needs of present and future users.
10.2 Role of Water Management
Sustainable water management needs a responsible use of water resources while assuring sufficient water supply to different users. This consists of the action of developing the best use of water resources under defined water regulations (Durham and Angelakis, 2005)

10.3 Best Practices related to Water Management

10.3.1 Rainwater harvesting is an expression where rain is intercepted on roofs where the run-off is directed into a tank where it is stored and used whenever necessary. Rainwater harvesting is used to supply water to the very building where it is located. It is possible to collect about 600 gallons of water falling on a surface of 1000 square feet.

Roof water collection is being practised in a number of countries that have a very wet weather, consequently lessons are being applied to European countries (Thomas, 1998)

The basic components of a Rainwater Harvesting system include:

- Catchment: roof to collect the rain
- Conveyance: pipes for directing from catchment areas into storage
- Storage: tanks where collected rainwater is securely stored
- Purification: purification of rainwater for potable use
- Distribution: system that delivers the rainwater,

10.3.2 Water Reuse - Water reuse through surface and groundwater is an ordinary custom in Europe aided by water standards. The reuse of water has been confirmed in water stressed areas to be a drought proof source of water and one of the most effective answers for water scarcity. (Durham and Angelakis, 2005)

10.3.3 Reduction of wastewater volumes through Closed Loop Cooling Systems – Plants firstly designed with an open-loop cooling system intended that water was used to cool essential equipment, treated and finally discharged into the local environment.

Installing a closed-loop cooling water system involves modifying abandoned or unused water storage tanks and installing a pump-house with cooling tower. Cooling water is recaptured and distributed through the cooling tower, where it is cooled by air. After which it is pumped back into the cooling system. This can help cut water consumption by 75% and reduce releases into the local water supply.

10.3.4 Reduction of water use – Toilets and urinals account for nearly one-third of water use in buildings. Low flush toilets and spray taps are becoming substitutes for predated fixtures that reduce water.

Source: http://www.epa.gov/watersense

10.4 Implementation Methodology

10.4.1 The implementation methodology for Rainwater Harvesting

The basic stages for implementing the system are:

1. Gutters must be easily connected under the roof to capture rainwater.
2. Gutters and downpipes are to be connected.
3. The tank can be placed as close as permits to the downpipe.
4. Downpipe has to be connected to the filter which is then connected to the tank **as shown in fig 1**

Filtering and parting of sedimentation with a filter is needed if the water is to be used for human consumption by preventing bacteria from getting to the tank.

Figure 1. Illustration of rain water harvesting system

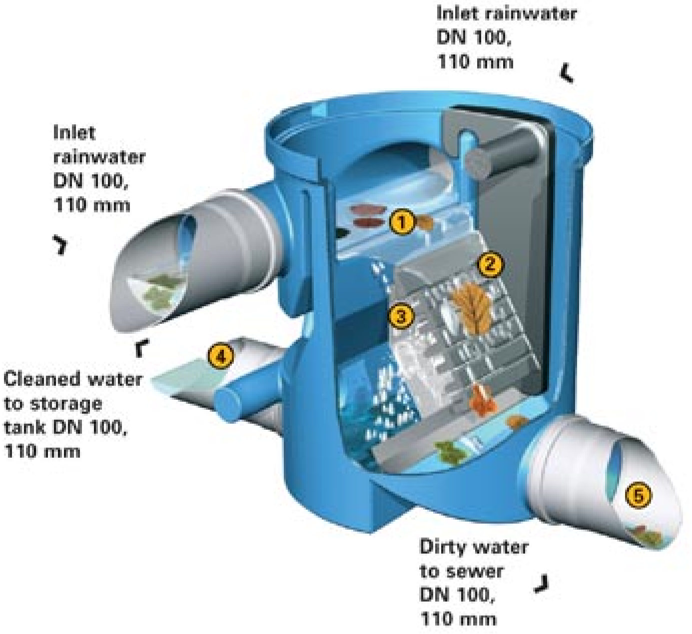


Figure 2. Rain Water Harvesting Filtration System

Source: http://www.freewateruk.co.uk/commercial-tank-filter.htm

10.5 Benefits of the Best Practice for Water Management

10.5.1 The benefits of rainwater harvesting can include:

- Relief of pressure on other water sources
- capability to build in areas with small water supply
- Safer and cleaner supply of water
- Lower cost
- Increases freedom from direct water supply providing water security
- Reduces topsoil loss and better plant growth

10.5.2 Water Reuse Benefits

- Helps reduce water use
- Potable substitution
- Lower energy costs compared alternatives
- Valuable and drought proof option for industry
- Reduces the crisis of overuse of surface and groundwater supplies

(Durham and Angelakis, 2005)

10.6 Limitations of the Application of the Best Practices

10.6.1 Limitations of Rainwater Harvesting

Several assumptions for installing rainwater harvest systems:

- A separate plumbing system is required to direct water from the rainwater harvesting system
- Captured rainwater has to be stored with first investment needing significant floor area.
- Life of the system coincides with the life of the building.

Hicks, B. (2008)

10.7 References

10.7.1 Books

Thomas, T.H. and Martinson, D.B. (2007). Roofwater Harvesting: A Handbook for Practitioners. Delft, The Netherlands, IRC International Water and Sanitation Centre. (Technical Paper Series; no. 49). 160 p.

10.7.2 Papers

Durham, B., Angelakis, A.N., Wintgens. T., Thoeye, C and Sala, L. (2005) “Water Recycling & Reuse. A water scarcity best practice solution”, “Proceedings of the Arid Cluster “Coping with drought and water deficiency: from research to policy making” conference”, Cyprus 12-13 May 2005.

Mohammed T. A., Mohd. Noor M. J., and Ghazali A. H. (2007) “Study on Potential uses of Rainwater Harvesting in Urban Areas”, Department of Civil Engineering, Faculty of Engineering, University Putra Malaysia

Thomas, T. (1998). 'Domestic water supply using rainwater harvesting', Building Research and Information, Vol. 26(2), pg. 94-101

10.7.3 Internet

http://www.watereuse.org

http://www.freewateruk.co.uk/commercial-tank-filter.htm

6.3 General Implementation Guideline

1 Define what is a BP;

2 Establish how to identify BPs;

3 Consult with experts and practitioners on strengths and weaknesses of methods for identifying and prioritising SUS-BP;

4 Find best practices by logging techniques and practices that people use and are proud of;

5 Look for patterns where particular techniques are frequently associated with good results;

6 Use peer groups to evaluate these practices;

7 Identify BPs that are not widely visible;

8 Align chosen business practices to the company business strategy and reject ones that are not;

9 Analyse to see if the economic benefits outweigh the ecological benefits and assess their business impact;

10 Consolidate variations of BP within the organisation;

11 Fill taxonomy with detail of BP relevant to the needs of the business and requirements needed for implementation;

12 Implement internally within the organisation to monitor and see the effects it has on the business, people or environment. The purpose of to observe if the BP still functions efficiently and effectively and to see its ecological and economical effects;

13 Transfer the best practice internally to other parts of the organisation

14 Monitor and measure returns after implementation

15 Extract guidelines by synthesising BP from a number of cases into general guidelines that can be used elsewhere.

16 Provide enough information to help users qualify the practice i.e. identify in which situations this practice has worked well.

17 Nurture communities and networks by knowledge exchange.

18 Use experts and practitioners to validate the BP guidance; apply feedback from practitioners to continually improve and build on BP.

7 DISCUSSION

7.1 Introduction

The last three chapters have looked in depth at the themes which have emerged concerning the development of a digital library.

7.2 Topic of Sustainability

With its large scale use of material and energy leading ultimately to displaced natural ecosystems, consumption of natural resources is at the heart of sustainability.

7.3 Approach to Research Methodology

Emissions waste and wastewater BPs have appeared most frequently in literature by 35%. This has been favoured most by authors since the topic of sustainability often begins with the impact upon the environment from waste. Energy and standards followed with similar measure as these are means toward sustainable development and is an increasingly growing area of concern for designers and managers alike. This further highlighted the level of importance for certain BP considered by some academics and industrialists in their writing.

Some BP varied slightly in description in the literature matrix, this is mostly down to geographic, cultural and industrial variations. Exact examples in description were mostly difficult to find but nonetheless these were found under similar names and descriptions. This helped to alleviate the gap in this study for the lack of journal association with BP and was considered a relatively quick and simple way of academic validation.

The commonly favoured BPs were related to maximised value through waste reduction, minimised use of energy and raw materials, minimised use of non-renewable resources, waste utilisation and reuse. Overall this was a very good exercise to help determine the strength of certain areas of sustainability at any one time, but it must be noted that this should be based upon finding the most current and up-to-date literature. If this is outdated then this may be of little use due to changes over time in understanding of technology and sustainability issues. Another influencing factor in this part of the study is unprofessional or unpublished works that have not travelled through the correct channels of validation. Professional publications through established bodies would lend a greater level of credibility to research.

A concern of the taxonomy design was that the document became somewhat difficult to manage when inputting more than one BP. The process of populating the taxonomy with information was more process orientated and had little practical orientation. This presents the possibility that this will become confusing for users who are inputting information and would therefore require meticulous attention to detail.

The difficulty of managing taxonomy should be reflected in the methodology and would better suit the input of individual BPs per taxonomy rather than the template which encapsulate many BPs. Allowing only a single BP lends it to becoming clearer so as not to confuse readers with information, therefore readers are required to methodically follow the section numbering to learn the all parts of the BP. This problem is alleviated if allowed to be developed into a software version. Careful consideration should be given when incorporating the taxonomy into software as a general user interface. This allows the taxonomy to be developed further to companies requirements is so wished.

The idea of digitally documenting BPs collectively is good but too much emphasis was placed upon finding particular examples to populate sections of the taxonomy. Searching for appropriate BPs for processes surpassed the overall objective. This was considered time consuming with too much importance given finding the correct BP to fall under the correct heading.

The construction sustainability development process has provided this project with a very useful model for any organisation to implement and adopt as a way of moving towards sustainability. The cyclic development concept proposed by Roberts (1990) is a good model if followed literally. However this is usually sought with problems in organisations since his concept is not aimed at business process reorganisation, but is geared toward sustainable technology. It is likely that concepts of sustainability can be found translated into other management concepts similar to lean but nonetheless, little by little and gradual adoption can ease and overcome these issues.

It was only once those descriptions of all the processes were defined, then could the process of locating and identifying correct BPs begin. Where exact examples could not be found these were substituted for similar ones in description. In practice, adopting the model was easier compared to understanding and defining each process because of their indistinguishable names. It was found that many of these BPs could be transferred between processes, for example reuse of buildings, materials and equipment could be transferred from Consumption through to Resource Recovery. This lends itself to the danger of duplication and therefore the library would require meticulous planning and management.

8 CONCLUSION

From the information obtained from the research, the following conclusions have been gathered:

- This study has provided a means for companies to capture, use and disseminate BP within their organisation and move toward sustainability.
- In order to safeguard present resources for future generation's companies need to in cultivate sustainability best practice in their processes.
- To appreciate sustainability best practices and what they can offer, companies need to triumph over any resistance to change.
- Companies lack a system for managing SUS-BP within their business and the BP framework has potential for use across industry.
- A high proportion of the proposed BP from this study consisted of the utilization of the cement kiln, proving positively its versatility and adaptability in helping to reduce environmental waste.
- The sustainability issue is well recognized and appreciated by industry but still there is need for industry to effectively apply SUS-BP and the sustainability model. The implementation of the SUS-BP is an on-going issue in many companies.

8.1 Limitations

Time was a limiting factor that somewhat hindered the complete required output. The ability to gather such vast information from research requires consideration and careful management.

8.2 Recommended future work

The cyclic process model proposed by Roberts (1994) this still needs more research. These are good models to follow but require a separate study in their own right.

Further work would require the acquiring and gathering quantitative data of BP implementation to gain full benefit of this study. Further study can also focus on gathering empirical data by implementing a few key best practices for use in the digital library.

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