

CRANFIELD UNIVERSITY



MARTIN HOLLIDAY

MAKING CONSTRUCTION PROJECTS MORE SUSTAINABLE  
THROUGH MATERIALS CHOICE

SCHOOL OF INDUSTRIAL AND MANUFACTURING SCIENCE

MRes THESIS

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CRANFIELD UNIVERSITY

SCHOOL OF INDUSTRIAL AND MANUFACTURING SCIENCE

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Making Construction Projects More Sustainable Through  
Materials Choice

Supervisor: Dr Emma Dewberry

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the degree of Master of Research

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Thanks also goes to MWH for their collaboration on this project, particularly to Annabelle and James for giving me both the confidence and context to carry out this research.

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## **Abstract**

Globally, the construction industry is responsible for the use of vast quantities of natural resources. These resources are often procured on the basis of their economic value, the cheaper the material, the more likely it is to be chosen to construct with. It is widely recognised that there are limits to the amount of raw resources available on Earth and that those that remain must be subject to careful management. It is becoming increasingly important for companies to show greater awareness of the growing issues of sustainability- concerning social, environmental and economic equities. One way of doing this is to incorporate 'sustainable' thinking into the early design phase of projects where opportunities exist for many environmental and social impacts to be addressed and minimised.

The aim of this project was to provide designers, engineers and architects with a materials selection tool to enable them to facilitate more enlightened design. Through more informed choice of materials, the projects and programmes of construction can be made less unsustainable and result in working to preserve the amount of natural resources available whilst simultaneously promoting social equity and economic viability.

The project aimed to address how a material selection tool could be utilised in real life construction projects. This aim was realised through working with MWH

(Montgomery Watson Harza), a global engineering and environmental consultancy firm, who provided an ideal opportunity for the tool to be developed and used in a pilot study.

The research looked at current environmental methods of selecting materials for building/construction purposes and sought to develop them into a more sustainable materials selection tool called the *Materials Matrix* (M<sup>2</sup>). The M<sup>2</sup> was developed for use by engineers, designers and architects within MWH and their operations in connection with the particular construction programme 'Trident West Agreement'.

The findings of this research suggest that there is a case and perceived need for a tool of this type that actually provides company employees with a choice of construction materials based on factors other than cost. Secondly there is a major lack of information regarding specific materials' social and environmental properties, particularly in relation to the information made available by material suppliers. However it is clear that the Materials Matrix has potential to provide a broader context of information for designers and engineers to achieve more sustainable solutions.

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## Terms of Reference

|                |   |                                                            |
|----------------|---|------------------------------------------------------------|
| AMP            | - | Asset Management Plan                                      |
| BRE            | - | Building Research Establishment                            |
| BSRIA          | - | Building Services Research and Information Association     |
| CIRIA          | - | Construction Industry Research and Information Association |
| CFC            | - | ChloroFluoroCarbon                                         |
| EA             | - | Environment Agency                                         |
| EIA            | - | Environmental Impact Assessment                            |
| EMS            | - | Environmental Management Systems                           |
| EPM            | - | Environmental Preference Method                            |
| GDP            | - | Gross Domestic Product                                     |
| GRP            | - | Glass Reinforced Plastic                                   |
| LCA            | - | Lifecycle Assessment                                       |
| M <sup>2</sup> | - | Materials Matrix                                           |
| MWH            | - | Montgomery Watson Harza                                    |
| NGO's          | - | Non-Governmental Organisations                             |
| OFWAT          | - | Office of Water Services                                   |
| TWA            | - | Trident West Agreement                                     |

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## **1.0 Introduction**

The following chapter will present the subject matter for the research and the context that it is placed in. This will entail an introduction to the use of sustainable materials in construction projects and talks about this in relation to both Montgomery Watson Harza (MWH) and the Trident West Agreement.

### **1.1 Introduction to the Project**

Montgomery Watson Harza (MWH) is currently investing time and capital into providing more sustainable solutions and services for its clients and is currently running a two-year programme looking at methods and practices by which they can make their projects more sustainable.

The research conducted in this thesis runs parallel to this bigger programme by MWH and will endeavour to look carefully at how MWH can make their projects more sustainable through the materials they choose to construct client sites, installations and projects. This will result in reduced environmental and social impacts whilst improving MWH's and their clients' profits through increased competitive advantage in addition to moving away from an unsustainable future.

### **1.2 Introduction to MWH**

Montgomery Watson Harza (MWH), formed by the 2001 merger of Montgomery Watson and Harza Engineering, is a modern consultancy firm working in the global environmental consultancy market, which is currently a very profitable market. In the UK alone it is currently worth £1 Billion and the sector's growth rate has been estimated at

around 25% year-on-year in the last few years. MWH Global (See Figure 1) offers design, construction, finance, operation, and maintenance services for projects in more than 30 countries in Europe, the Americas, the Middle East, and the Asian/Pacific Rim region. With Montgomery Watson founded in 1945 and Harza in 1920 the newly founded MWH Global has deep roots and a firm foundation for which to strive for further success.



Figure 1, MWH logo.

Over the last five years or so the environmental consultancy market has matured somewhat to also encompass social and economic accountability, resulting in the discipline of sustainability. This has presented the increased market opportunity for companies such as MWH to expand from their core environmental consultancy services to more comprehensive sustainable consultancy services and solutions for their clients. MWH states that they 'Strive to become a global leader in the delivery of projects and solutions that improve the quality of life, and the business efficiency of their clients' (MWH, 2002). The Company is placing increasing weight globally on sustainability, with particular attention to energy and global warming issues. MWH is aware of the multidimensional nature of sustainability and the concept of the triple bottom line (Elkington, 1997) which recognises the notions of a sustainable business (Economic), a sustainable society (Social) and also a sustainable environment. In the UK there is a particular focus in pioneering the application of sustainability into MWH practices. MWH recognise that through their projects and programs they have the potential to reduce environmental, societal and economic impacts and in turn improve the sustainability of MWH, their projects and subsequently their clients.

### **1.3 Introduction to Project Context**

MWH is the industrial collaborator for this project and the research has been undertaken in the context of the Trident West Agreement (TWA), one of MWH's biggest project programmes. The research generated will not only be applicable to the Trident West Agreement but more widely to MWH and all of their construction projects.

The Trident West Agreement is an agreement which sees the consultant MWH working in partnership with both an established contractor and the Client, a well-known water plc. All three of these establishments are co-located in Reading and work on a variety of projects including pipelines, tanks and chambers, and buildings and enclosures. The main purpose of the alliance is to actively seek solutions which require no (or minimal) capital investment by making the best use of the capabilities of existing assets.

With regard to resources and construction, the Trident Agreement sees that a single integrated team, with no duplication of resources, will undertake these activities. The Trident Alliance has an Environmental Management System (EMS) in place and the environmental performance of the alliance will be measured against the following key principles:

- i) Treatment Processes
- ii) Waste Management
- iii) Storage, Handling and Use of Hazardous Materials
- iv) Site Run-Off
- v) Nuisance, Conservation and Archaeology

The Trident West Agreement runs on 5 year AMP (Asset Management Plans) as defined by OFWAT (Office of Water services) the economic regulator in the water industry, which is also carried out in conjunction with the EA (Environment Agency). The Trident

Agreement is currently in AMP 3 which runs from 2000-2005. The basic structure of what occurs in an AMP at a strategic level is outlined below:

- i) Year 1, planning stage. What is to be carried out, designs, auctioneering for suppliers. Should buildings be refurbished or constructed from new?
- ii) Year 2+3, the delivery of programme. Building and construction.
- iii) Year 4+5, tendering for suppliers the next AMP period usually 2 years before the start of the next one. It is at this stage that strategic decisions are made regarding the upcoming AMP.

It has been important to understand this process at a strategic level, early on in the project, because it may influence any decisions made about the use or procurement of sustainable materials in any of the Trident West projects. This could mean any new materials or practices arising from this work may only be integrated in to the Trident West design process in time for the next AMP period and not the current one.

#### **1.4 Research Question**

The objective of this thesis is to provide an assessment of current practices or methods of evaluating the environmental impacts of construction materials and look towards creating a methodology by which construction materials can be made more sustainable whereby the economic, environmental and social factors are all considered. This provides the following research question overleaf:

*'Can MWH, in the projects they tackle within the Trident West Agreement, make their activities more sustainable particularly through their choice of construction materials?'*

## **1.5 Project Aims and Objectives**

The research area is focused through the use of aims and objectives established at the beginning of the project. These are outlined below.

The aim of this research is to provide information regarding the sustainability of materials used in the construction industry. In addition it is intended to develop a materials selection tool that will enable designers and engineers to choose materials for construction projects that increase the overall sustainability of the projects that MWH and Trident West are involved with.

The objectives of the research are as follows:

- i) Research current literature surrounding sustainability, its association with the construction industry and sustainable materials.
- ii) Draft a questionnaire for suppliers and manufacturers to prompt them on their actions toward sustainability.
- iii) Develop an understanding of current design processes within MWH.
- iv) Look at a past project MWH has conducted in addition to understanding the current projects and practices within Trident West through time spent within the Company.

- v) Develop a tool for use by the designers and engineers within Trident West to aid them in selecting more sustainable materials.
- vi) Identify any key themes that are prevalent throughout the research and consider how they can be used to make the projects MWH and Trident West carry out more sustainable.

## **1.6 Project Deliverables**

In order to address the research question above and the aims and objectives, the following deliverables will be produced:

- 1) A literature review to provide the context of sustainability and the association the construction industry has with it including a detailed analysis of the potential sustainability of materials.
- 2) An assessment of current methods of selecting materials for use in the building and construction industry.
- 3) Original research involving questionnaires to suppliers, manufacturers and members of the Trident West Agreement concerning the design procedures, site activities and materials use and procurement.
- 4) A materials matrix to aid engineers and designers within Trident West to choose the most sustainable material for a given job.
- 5) Summary and review of the factors currently limiting the adoption of a sustainable materials policy within the Trident West Agreement.
- 6) Recommendations for further research that will enable greater understanding in this area.

## **1.7 Project Execution**

The project took place over a ten-week period, from June to August 2002. The first four weeks were spent conducting desktop research for the literature review and background information on sustainability, the construction industry and sustainable materials.

The subsequent six weeks consisted of a combination of further desktop research supplemented with regular visits to both MWH's UK headquarters in High Wycombe, Buckinghamshire, and the Trident West installation at Reading, Berkshire. It was predominantly at these two sites that liaisons with managers and employees at a number of levels occurred to achieve the project results. In addition suppliers to the Trident West Agreement were also interviewed.

## **1.8 Summary of Project Achievements**

The project succeeded in accomplishing the following achievements:

- i) Achieved an understanding of the current climate regarding sustainability and the construction industry and sustainable construction materials through the literature review.
- ii) Detailed a comparative analysis of current methods of selecting materials with environmental considerations.
- iii) Developed a Materials Matrix ( $M^2$ ) that expands on the literature regarding the environmental considerations of materials to make them more sustainable overall.
- iv) Achieved an understanding of MWH design processes and how sustainability can be integrated into them.

- v) Highlighted areas that are perceived as potential 'blockers' for sustainability within MWH and specifically the Trident West Agreement.

## **1.9 Thesis Structure and Content**

The structure of the thesis is divided into eight chapters. These are described as follows with a research map summarising the structure of the research at the end.

### **Chapter 1: Introduction**

A brief outline of the project details including the research question, the context of the research, the deliverables and a summary of the outcomes.

### **Chapter 2: Literature Review**

The literature review follows a funnel type approach, starting with information about sustainability focusing down to details about sustainable construction materials. It provides an insight into current understanding of these issues whilst highlighting the perceived 'gap' the research aims to bridge.

### **Chapter 3: Methodology**

This chapter describes the methodologies that were used and developed to satisfy the research deliverables.

## **Chapter 4: Comparative Analysis of Environmental Guidelines for Selecting Construction Materials**

This chapter gives a brief explanation and comparison of three of the current guidelines that allow the selection of construction materials in an environmentally aware fashion.

## **Chapter 5: Suppliers to the Trident West Agreement and Sustainable Procurement**

The current situation regarding suppliers of construction materials to the Trident West Agreement is explored to define the areas where sustainability is a concern. This is important in emphasising the need for future work in this area. The results of questionnaires to suppliers and manufacturers to the Trident West Agreement are discussed here and also how this affects the remainder of the research and its findings.

## **Chapter 6: Sustainable Materials Selection Tool**

In this chapter the concept of the Materials Matrix ( $M^2$ ) is explored and developed as a tool for designers and engineers including the inputs and requirements of project team members from Trident West. Sustainable materials are also explored further here including definitions.

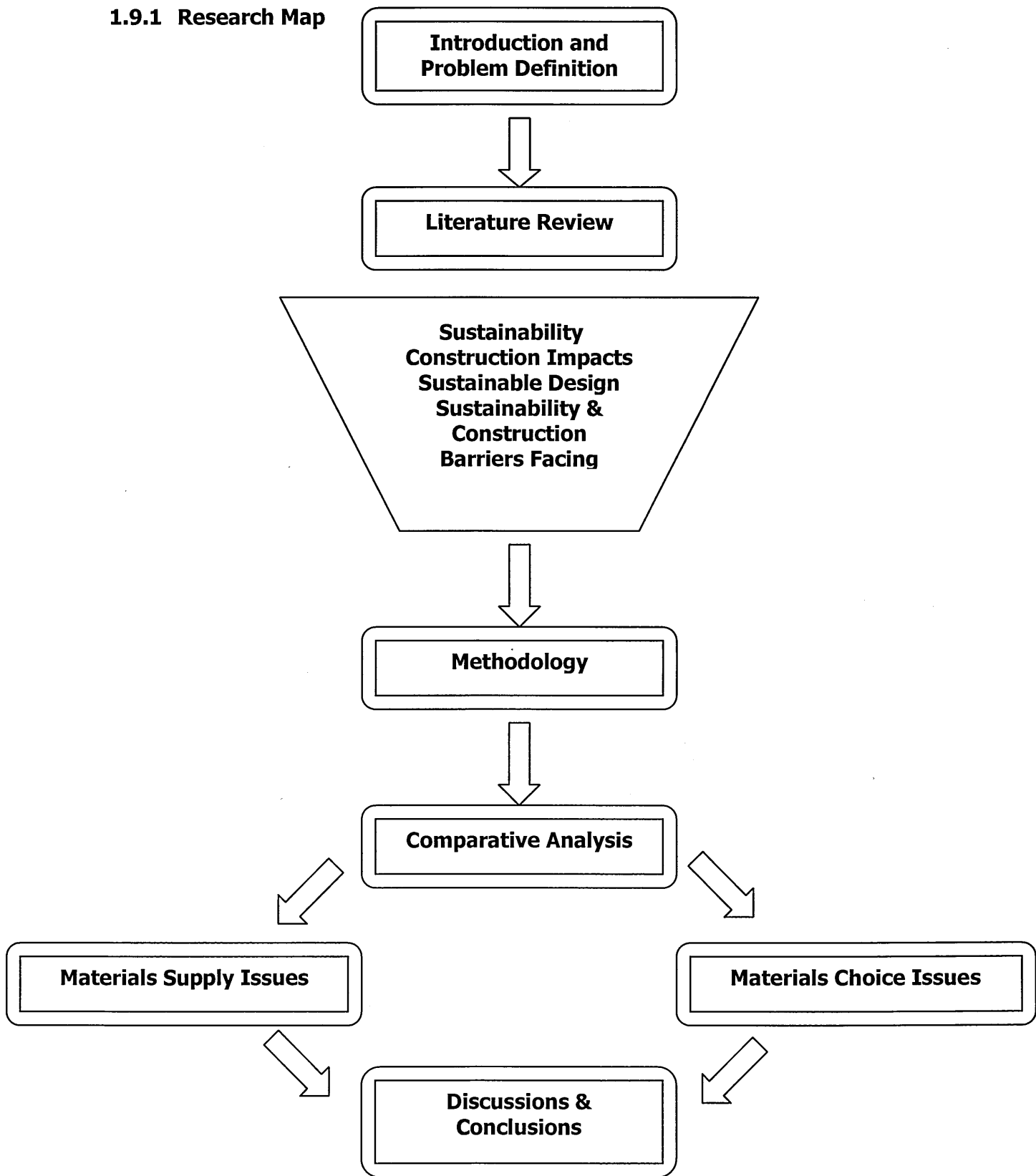
## **Chapter 7: Discussion**

This chapter focuses on the discussion of the applicability of the research to MWH and the Trident West Agreement. It will focus particularly on how the proposed methodologies can be integrated into the design process and the transferability of these more generically within MWH.

## **Chapter 8: Conclusions and Future Work**

Here the project conclusions are highlighted examining the benefits to MWH and the Trident West Agreement as well as society at large. The final section of the thesis looks at denoting any further potential research 'gaps' as well as suggesting strategies to meet future needs.

**1.9.1 Research Map**



## **2.0 Literature Review**

### **2.1 Introduction to Literature Review**

The purpose of this literature review is to capture and document the current knowledge regarding sustainability and how it is related to the construction industry. More specifically though it focuses down to the issue of materials and how they can contribute to the improved sustainability of construction projects. The literature review begins by talking about the concept of sustainability and moves on to how the construction industry has an important role to play in operationalising this agenda. A particular focus is the nature of the materials currently used by the construction industry and a review of emerging literature that promotes the case for the use of sustainable materials and sustainable materials procurement.

### **2.2 Sustainability**

We are currently in the process of a paradigm shift with respect to how society views and interacts with the social, economic and environmental realms of the Earth, (Rowledge, 1999).

The concept of sustainability is one which is receiving more widespread attention as we move in to the 21<sup>st</sup> Century. It represents the maturing green or environmental movement that has been prevalent during the 1980's and 1990's and looks to encompass three main areas; Economic Social and Environmental (McClaren, 1998). The most internationally recognised definition of sustainability or sustainable development (The two terms are interchangeable) comes from the WCED (World Commission on Environmental Development) and Gro Harlem Brundtland the then chair person, and

previous Prime Minister of Norway, defining it as 'Development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED, 1987). This WCED report follows the Club of Rome's 'Limits to Growth' report in 1972 which highlighted that anthropogenic actions were not sustainable at projected levels and that exponential growth would lead to poverty, resource depletion and over population to name a few key issues (Meadows, 1972). The term sustainability is used to describe the lifestyle that mankind must lead to successfully maintain itself and the planet. It is however not a simple concept but one that entails complicated interactions between the environment, the economy and the social welfare of people globally (Blofeld et al, 2002), See Figure 2 below. Furthermore, sustainability should not be seen as a precise goal, it is more of a criterion for attitudes and practices (Trzyna, 1995).

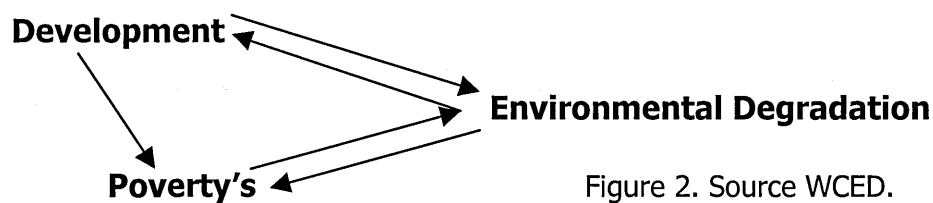


Figure 2. Source WCED.

Although this term of reference lacks definition, in the 15 years that have passed since, much has happened with regards to sustainability and sustainable development. The world summit in Rio De Janeiro 1992, further raised the profile of these issues and a general acceptance of sustainability by politicians, non-governmental organisations (NGO's) and business leaders, (Dylick, 2002). This was due to concerns over the affect of unlimited economic growth on the environment and world communities (Hill, 2001). The Earth summit saw a gathering of representatives from over 176 different countries, which included more than 100 heads of state. The summit agreed that voluntary global action was necessary to be designed to deliver sustainable development (McClaren,

1998). A number of initiatives and plans, mostly environmental, including the Kyoto and Montreal protocols have been set up over the years to move humanity away from unsustainable practices. The results of these will be reviewed very soon at the 2002 Johannesburg summit to be held at the end of August. This will also pave the way for the next ten years of working toward sustainability globally. I feel that we are finally in the process of moving away from an all-consuming society that sees the environment as a set of resources to be exploited exponentially and that a process of change toward sustainability is underway.

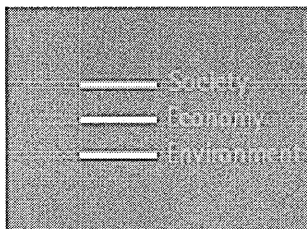


Figure 3. The Triple Bottom-Line. (SustAinability.Com)

John Elkington describes the scenario we are now facing as the 'Triple Bottom Line' (See Figure 3.) (Elkington, 1997), the three lines represent society, the environment and the economy. It summarises that 'society relies on the economy, the economy relies on the global ecosystem, whose health represents the ultimate bottom line', (SustainAbility, Web). McClaren in his book, *Tomorrows World*, depicts a similar vision of the domains of sustainability (See Figure 4.) but uses three circles to represent the social, economic and environmental domains of sustainability. The areas that crossover denote the complex interrelationships and multidisciplinary nature of sustainability with the true notion of sustainability lying within the centre and the management of all of the areas necessary to facilitate sustainability successfully.

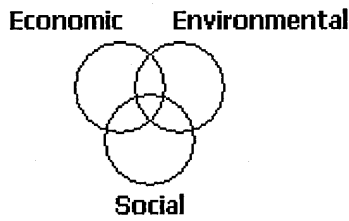


Figure 4. The Domains of Sustainability (McClaren, 1998)

### 2.3 Construction Industry Impacts

The construction industry is one of the biggest industries globally and as a result has one of the greatest potential impacts on sustainability and sustainable development in the world today. Anink et al. (1996) highlight that 50% of material resources taken from the natural environment are related to buildings, over 50% of national waste production comes from the building sector and that 40% of the energy consumption in Europe is also building related.

Birkeland (2002) further explains that the construction industry is arranged in a way which is not only wasteful of energy, resources and land but also increasingly human skills and talent. Exact figures regarding the impacts that buildings and the construction industry have on various elements of the global ecosystem are not readily available but some of the primary concerns are described below using Birkeland's (Birkeland, 2002) topic areas as a focal point with my own interpretations. Forests are one of the most valuable resources that the Earth has to offer. They act as carbon sinks and the process of photosynthesis is inextricably linked to the survival of the planet and humanity. It is estimated that the Earth's surface has lost some 50% of its forest cover (Brown et al. 1996), that buildings account for one quarter of global wood harvests and that in the USA over 50% of all wood is used in buildings (Roodman et al, 1995). Water is another important focal area concerning construction industry impacts; it is an essential pre-

requisite for any life on Earth. Buildings, it is estimated, consume one-sixth of all fresh water supplies (Brown et al. 1996). In the USA the Environmental Protection Agency has readily identified over 700 regular pollutants in the drinking water, 20 of these have been distinguished as carcinogens (cancer causing substances). Carbon Dioxide is another major concern, as a known greenhouse gas and one of the greatest contributors to global warming in the world today. Over the last 100 years atmospheric CO<sub>2</sub> levels have risen by 27% (Pout, 1994). One quarter of this is directly connected to the burning of fossil fuels such as coal, oil and gas to provide energy for existing buildings. Further to this the energy use in buildings in the UK accounts for some 48% of total CO<sub>2</sub> emissions (Pout, 1994). Global energy consumption is a major issue when considering the impacts of the construction industry. A figure of 20% relates solely to the process of construction alone of annual energy consumption (Tucker, 1994). This does not consider the amount of energy it takes to provide power and heat to buildings globally each year once constructed. The total figure for the amount of energy consumed in building, construction and services in the UK is 66% of annual energy consumption (Vale, 1994).

With waste disposal becoming a major issue globally and in countries like the UK where space is at a premium, the amount of waste produced needs to be drastically reduced. Building waste from industrial nations currently accounts for 44% of landfill and 50% of packaging waste (Birkeland, 2002). These vast quantities of waste lead to issues regarding the supply of natural resources. Natural resources are known to be finite in their availability. However, buildings account for over 40% of the world's annual energy and raw materials consumption (Roodman et al. 1995). It can be concluded that

resource depletion cannot continue at this rate and is an area that the construction industry needs to improve its performance in.

Having highlighted some of the major impacts that the construction industry is responsible for I will now move on to explain the role that sustainable design has to play and how it can help improve the performance of the construction industry.

## **2.4 Sustainable Design**

In this section the role of Sustainable and Ecological Design is explored as a suitable vehicle for moving the construction industry away from unsustainability and toward a more sustainable future. The two terms sustainable and ecodesign are considered interchangeable in this literature review as both consider the wider impacts and aspects of design.

Designers of buildings and their service systems play a key role within the building sector. Consciously or not, they regularly choose between alternatives with a greater, or lesser, environmental impact (Anink et al. 1996). Van Der Ryn & Cowan (1996) define design as "The intentional shaping of matter and processes to meet a perceived need or desire". They then go on to say that in the past the design process in many industries including the construction industry has been either consumer or technology orientated. The environment or sustainable development issues have rarely been taken into account and the process can often be defined as 'dumb design' with the realisation that design has not been given enough context (Van der Ryn & Cowan, 1996). Through the late 1980's there was a rapid growth in the number of green consumers who were thought to record their support for the environment by purchasing "Planet Friendly" products (Whiteley, 1993) and with the advent and increase of the green consumer base, green

or ecological design practices became increasingly common. Van Der Ryn & Cowan define Ecological Design as: "Any form of design that minimises environmentally destructive impacts by integrating itself with living processes" (Van Der Ryn & Cowan, 1996). Originally not all people believed in the philosophies of green or ecodesign and Stephen Bayley, the then Director of the Design Museum and perhaps one of the biggest pundits of consumerist design, wrote in 1991, 'Green design is a foolish idea, something created for and by journalists" (Whiteley, 1993).

Despite this though ecological and green design have evolved over the last decade and many designers now look at their projects in a more sustainable fashion, considering the economic, social and environmental impacts. Van Der Ryn and Cowan (1996) highlight the need for the construction industry and designers and architects to look at the entire life cycles of the materials they use and argue that they should design in ways that allow these materials to be reclaimed. They continue by suggesting three critical strategies for the particular issue of resource loss:

- 1) Conservation – Slowing down the rate at which natural resources are used.
- 2) Regeneration – The method of preserving and protecting the natural resources we have left.
- 3) Stewardship – This is the technique by which natural resources are continually maintained and are reinvested in.

Birkeland's opinion supports the suggested notions above and she states that "there are many missed opportunities to create symbiotic relationships between the processes of extraction, distribution, and construction, and to recapture resources and energy that are presently wasted" (Birkeland, 2002).

The design of the built environment has held a minor position in the literature of environmental management and sustainability. Yet inappropriate design determines most of the avoidable environmental impacts which environmental protection laws, policies and programmes can only mitigate (Birkeland, 2002).

Because environmental professionals and academics have failed to appreciate the centrality of environmental design to sustainability, they have underestimated its potential as a method for environmental management and problem/prevention solving (Birkeland, 2002). We need to ask questions, to intervene, to render visible what has so long been hidden from public discussion: that sustainability, or its lack, is inseparable from the particular characteristics of objects, buildings and the landscapes we design (Van der Ryn & Cowan). Simon (From McAlloone) eloquently states that even though environmentally conscious design may inevitably contribute toward promoting sustainability, it does not directly aim at achieving sustainability. From this Simon concludes that the process of sustainable design should create sustainable products which "must generate capital for future generations to offset its use of natural resources" (Simon, 1996).

All of the above information regarding ecodesign and sustainable design can be summarised in the words of Van der Ryn & Cowan (1996), "Design must be embedded in a wider cultural and ecological context". This provides a reasonable cause to believe that sustainable design is a suitable vehicle for achieving a greater level of sustainability within the construction industry. Through enlightened design in the first instance many social and environmental impacts can be completely avoided. Applying this further to the specific choice of materials used in construction at the Trident West Agreement, it is

perceived that the design stage of a project is the best time to introduce sustainability to the construction industry. This concept is detailed below.

## **2.5 Sustainability and the Construction Industry**

Sustainable construction is part of sustainable development which is about ensuring a better quality of life for everyone, now and for generations to come (DETR, 1999).

Sustainable construction can be defined as the application of sustainable development to the construction industry (CIRIA C563) or alternatively as "the creation and responsible management of a healthy built environment based on resource efficient and ecological principles (Kibert et al. 1994 from BSRIA). The construction industry accounts for some 10% of GDP (Gross Domestic Product) and employs about 1.5 million people (DETR, 2000). The buildings and structures the industry creates permanently alter our society and environment. Energy consumed within domestic and commercial buildings produces one-third of the UK's CO<sub>2</sub> (CIRIA C563). The industry consumes six tonnes of material per year per person and produces tens of millions of tonnes of waste, a significant proportion of which is materials delivered to site and left unused. Clearly, improving the performance of the construction industry is vital to the delivery of sustainable development (CIRIA C563).

The aims of sustainable construction are to produce structures that enhance the quality of life and protect the environment, and to do so profitably and fairly. The current performance of the industry is not compatible with these aims; it is simply unsustainable (CIRIA C563). Two government reports, Re-thinking Construction (DETR, 1998) and the Government's Sustainable Construction Strategy (DETR, 2000) emphasise the need for a culture change within the industry.

To deliver more sustainable construction practices action is required from all those engaged in constructing and maintaining the built environment; these include those who provide design, consultation and construction services. A sustainable construction strategy needs to encompass the complete lifecycle of a structure from the initial concept right through to demolition and site remediation (CIRIA, 2001). The diagram below (See Figure 5) from CIRIA report C563 exemplifies how all stakeholders involved with the construction industry from clients to contractors, at each stage of the construction lifecycle, can take simple actions to deliver more sustainable solutions.

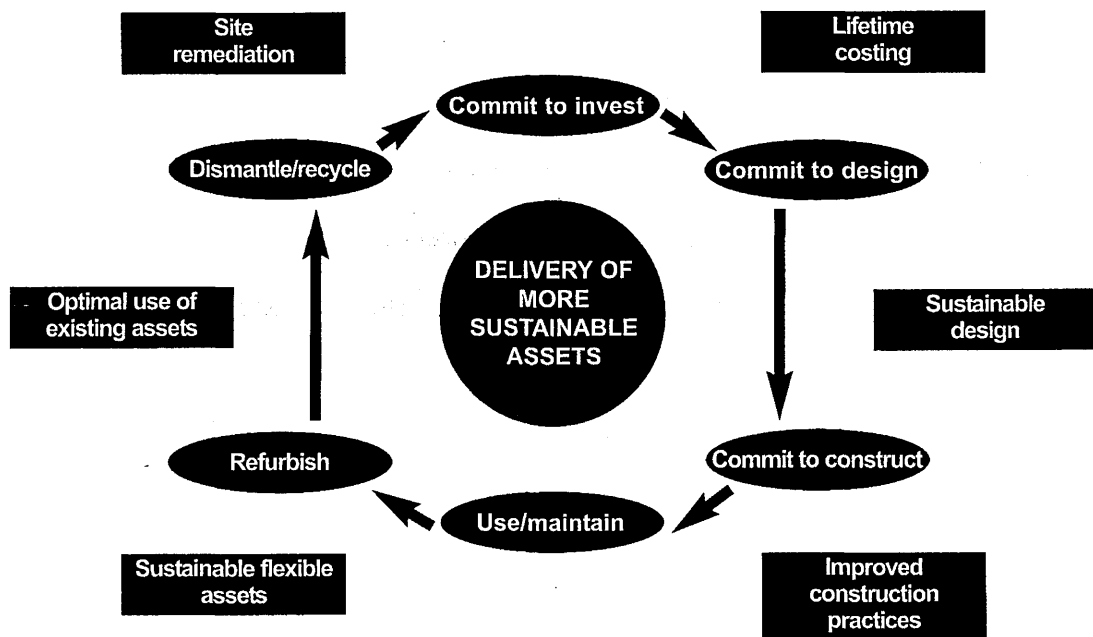


Figure 5: Lifecycle of a sustainable construction project (Source: CIRIA, 2001)

CIRIA report C563 written by the Construction Industry Research and Information Association, a major authority on new concepts in the building industry, regards sustainable construction indicators and is a seminal text regarding sustainable

construction at the moment. Its views are echoed in this section of the literature review but are used in addition to my own opinions. The report (CIRIA, 2001) suggests that sustainable development and sustainable construction require the careful balancing of the following four factors:

- 1) Effective protection of the environment
- 2) Prudent use of natural resources
- 3) Social progress which recognises the needs of everyone
- 4) Maintenance of high and stable levels of economic growth and employment

These four factors fully encompass the three realms of sustainability and highlight in particular that careful use and management of natural resources is necessary.

A strategy for the construction industry to achieve a more sustainable future has been the subject of a report by the then DETR - (Now DTI, DEFRA & DTLR) which was developed in close conjunction with industry representatives and consultancies to improve the performance of the construction industry as a whole. 'Building a Better Quality of Life' (DETR, 2000) highlights a number of key objectives that are necessary for working toward sustainability. They are as follows:

- 1) Be more profitable and more competitive
- 2) Deliver buildings and structures that provide greater satisfaction, well-being and value to customers and users
- 3) Respect stakeholders and treat them fairly

- 4) Enhance and protect the natural environment
- 5) Minimise its impacts on the consumption of energy (especially carbon-based energy) and natural resources

(Source DETR, 2000)

In summary the document "states the need for a culture change within the industry and seeks to provide the catalyst for this change by promoting awareness and understanding of the issues and identify priority areas for action" (CIRIA, 2001).

The Construction Best Practice Programme (CBPP, 2000) recognises that this must involve all those that develop, plan, design, build, alter, or maintain the built environment and that this should also include building materials manufacturers and suppliers in addition to clients and those end of use occupiers.

The CIRIA report goes on to suggest that within the four key factors of sustainability mentioned on the previous page, ten key themes for sustainable construction have emerged from consultation within the construction industry. They follow the pattern of the existing literature on sustainability reviewed in 2.2, in that they consider the three domains of sustainability, economic, environmental and social (McClaren, 1998).

Summaries of each of these three areas are as follows:

**i) Effective protection of the environment and prudent use of natural resources**

This is the area concerned with the environmental aspects of sustainability in relation to the construction industry. Four key themes are highlighted here and could provide focus for any issues arising from the research.

The first key theme looks at pollution, a widely recognised problem in the construction industry and the focus is placed on both mitigation and management of pollution from construction sites in addition to more rigorous transport planning including the movement of materials to and from site.

The second key theme looks at the protection and enhancement of biodiversity. Areas for concern here are turned toward habitat creation and environmental improvements on sites in addition to optimising the use of brownfield sites as opposed to using green field sites, which would further affect biodiversity levels. The last factor in this second key theme looks entirely at the concept of environmentally sensitive design and construction, an area that is in complete accordance with the idea of sustainable design in 2.4 previously.

The third key theme in the environmental domain focuses directly on the issue of improved energy efficiency. Concepts include the designing of whole life costs and the use of local supplies and materials with low embodied energy values to conserve and manage the amount of energy used in construction processes that are currently too wasteful.

The last key theme in the environmental area looks at the efficient use of resources, which is of particular interest as it relates directly to the subject of this research project.

Principle concepts look at the need to have waste minimisation and management measures in place to ensure so many resources are not wasted. Also the reuse of existing built assets which negates the need for new built assets and therefore more natural resources. It also looks at the principles of lean design and construction in addition to the increased use of recycled and sustainably sourced products and materials

for use in construction. Lastly it deals with the issue of water conservation, the impacts of which have already been reviewed in 2.3.

## **ii) Social progress which recognises the needs of everyone**

This section of the guidelines is specifically looking at the social dimension of sustainability and incorporates three key themes.

The first theme looks at respect for staff and includes issues such as provision of equal opportunities, maintaining morale and encouraging employees to participate in decision making processes.

The second key theme involves the construction industry working more closely with local communities. This area is more closely related to the use of sustainable construction materials through initiatives that minimise local nuisance and disruption whilst simultaneously contributing more effectively to the local economy. This idea of working more closely with local communities also concentrates on delivering structures and buildings that enhance the local environment. Again this can be related directly back to the materials used in a building. If they are more sustainable then there is a good chance that it will make the surrounding community more sustainable too.

The third and final key theme in the social dimension looks at partnership working. This includes working on building long-term relationships with clients and suppliers. The Trident West Agreement that is the context for this research would appear to be an excellent example of this and the relationships with suppliers of materials could be cultivated further to the mutual benefit of all concerned. Other factors in this section include the notion of being a good corporate citizen and contributing to sustainable development globally.

### **iii) Maintenance of high and stable levels of economic growth and employment**

The final area of the guidelines looks at three specific key themes within the economic aspect of sustainability and construction.

The first key theme looks at the increased productivity and profitability of the construction industry with particular reference to sustained consistent profit growth.

The second key theme concentrates on the notion of improved project delivery through measures such as client satisfaction and minimising construction defects.

The third and final key theme is the monitoring and reporting of economic performance against targets. This is a process that looks to be carried out by using benchmarking procedures against other construction industry companies in conjunction with company reporting.

These identified areas and key themes highlight a need for much work to be carried out on the construction industry to make it more sustainable. Through looking at these topic areas I have now earmarked areas for particular concern that are related to the use of natural resources and materials in addition to having identified sustainable design as the most suitable vehicle by which to achieve sustainability in the construction industry. This moves the focus of the literature on to any perceived barriers that face the construction industry in its mission toward sustainability and how to get around these.

#### **2.5.1 Potential Barriers Facing the Construction Industry and Sustainability**

A resource guide by the Building Services Research and Information Association (BSRIA, 1999) focuses on those issues that are perceived as future pressures regarding sustainability in the building services industry and summarises the main impacts that the

construction industry is accountable for. A large quantity of environmental impacts are noted including the use of large quantities of energy and materials and significant generation of pollution to land, air and water. In this context the obvious pressure is to reduce the use and consumption of valuable resources and to reduce the amount of pollution generated. The guide explains that this is no easy task and that for instance, it is important to distinguish between the energy embedded in the materials and used in their transportation to site and that energy which is consumed during the lifetime of the building. Similar distinctions apply to the huge demands of materials for a new site versus the relative small demands placed by the occupation requirements (BSRIA, 1999).

The guide highlights the following fifteen issues as those which have the greatest potential to block or disrupt the transition to a more sustainable construction and building services industry. It states "These fifteen future factors have been identified as having a likely significant influence on the level of sustainability achieved by the UK construction industry and, in particular, the building services industry" (BSRIA, 1999).

They are as follows:

- 1) Globalisation
- 2) International policy and politics
- 3) Climate change
- 4) Disasters – man made and natural
- 5) European policy and politics
- 6) Energy markets and supplies
- 7) Development in energy technologies
- 8) Use and availability of resources

- 9) Business and commercial attitudes
- 10) UK government policy and legislation
- 11) User and consumer attitudes
- 12) Society, health, transport, education and communications
- 13) Water resources
- 14) Waste management
- 15) The construction industry

(Source: BSRIA, 1999)

With these issues clearly identified as areas of concern the research is closely aligned to number 8) on the list and the use of more sustainable materials in construction projects can only serve to alleviate such worries. With the reasons for carrying out the research now firmly established the reasons why construction companies need to carry out these initiatives is explored next.

### **2.5.2 Business Case for Sustainability in the Construction Industry**

The case for businesses to adopt and develop sustainability is not strong enough in just ethical or concerned terms. Businesses find that they increasingly need a financial incentive to adopt such strategies and that any environmental or social benefits are just ancillary to economic savings.

Many companies in the construction industry do not yet realise the business case for achieving or aspiring to sustainability. Enlightened industry leaders however realise that the performance of the construction industry as a whole is unsustainable and that future changes and reforms are necessary. The support of such ideas needs top level support and the government has motioned that it intends to stimulate those changes that are

deemed necessary through not only fiscal and regulatory controls but by also encouraging and stimulating better practice within the industry through its role as a major construction client (CIRIA, 2001).

In his thesis, McAloone (2000) states that the motivation for companies in industry to conform to steady environmental improvement comes in the shape of three main drivers. These are shown below:

- i) Legislation**
- ii) Competition**
- iii) Consumer Pressure**

An ever increasing number of legislative drivers are prevalent in today's global industries and more specifically in certain industries. They range from the EPA 1990 (Environmental Protection Act) that is applicable to all UK companies right through to international pressures, for example the Montreal protocol against the use of CFC's (Chlorofluorocarbons).

It is common that in any given industry, one company often pioneers in improving their environmental performance and competitors then further try to improve their own. This can lead to continual improvements in an industry as companies try to stay abreast of one another so that any one company does not have more competitive advantage than another.

The growing green consumer base over the last two decades has been perceived to have a positive effect on the number of 'green' products purchased. McAloone (2000)

even highlights that during the late 1980's and the 1990's consumers were even prepared to pay a premium for 'green' goods or products.

The construction industry is a major polluter of the environment. In 1997, the industry was directly responsible for 588 water pollution incidents (4% of national total) with fines for some individual incidents exceeding £10,000.

The Environment Agency (EA) considers the current environmental performance of the industry to be unsatisfactory and in the medium-term regulatory controls may therefore increase.

"The construction industry has not done enough to reduce pollution and waste; to recycle materials; it persists in taking too short a term view of the future and does not value the environment in all the business decisions it takes."

*Ed Gallagher, Chief Executive, Environment Agency*

(Source, CIRIA, 2001)

CIRIA concludes that the effective management of environmental performance produces benefits by reducing the risk of non-compliance with regulatory requirements and hence minimises the financial penalties and negative publicity such breaches cause.

The business case for more sustainable construction is increasingly attractive as structural barriers to improvements are reduced or removed. The government has signalled its intention to stimulate the required changes and is encouraging companies to respond. In the medium-term, companies that want to thrive must therefore innovate and deliver more sustainable built assets (C563).

## **2.6 Sustainable Materials in the Construction Industry**

The security of the European Union's (EU) energy supplies together with concern for the environment have led to continued interest both in the energy efficient design of buildings, which currently account for close to 50% of the EU's total energy use, and in the choice of sustainable materials (Euro Directory, 1995). The construction industry is a major consumer of natural resources. The production, use and disposal of building materials accounts for significant quantities of energy and resources both internationally and in the United Kingdom (UK) (BRE, 1998).

The annual net change from rural to urban land use is estimated to be 6,500 ha and 260 million tonnes of minerals are extracted per annum for aggregate and construction product manufacture (DETR, 2000). The aggregates and landfill taxes and changes to the Waste Management Licensing Regulations are increasingly making recycling of construction materials a commercial necessity. UK construction of demolition site waste currently accounts for 20 – 24 million tonnes each year and represents about 6% of the total waste produced per annum in the UK (CIRIA, 2001). In total, about 30 – 40% of construction and demolition waste is currently sent to landfill, presenting a considerable opportunity for further improvement in materials recycling and cost saving (CIRIA, 2001).

Significant energy savings and reductions in environmental pollution can be achieved in the buildings sector through enlightened design, the use of renewable energies and the appropriate selection of components and materials for new and upgraded buildings (Euro Directory, 1995). As awareness of the environmental impacts of these processes has increased, many construction professionals and property owners have sought to

take more account of the environmental impacts arising from their selection of building materials and components (BRE, 1998).

The BSRIA resource guide mentioned in 2.5.1 highlighted fifteen potential future pressures regarding the construction industry and sustainability, one of these concerns the use and availability of resources. These include fossil fuels such as coal and oil, minerals like granite or slate, metals like iron and gold and numerous other raw materials. BSRIA (BSRIA, 1999) recommends that it is necessary to work nationally and internationally to address local, regional and global problems so that environmental limits are not breached and valuable resources are not wasted.

The resource guide also highlights the following potential pressures specifically regarding the use and availability of natural resources that are listed below:

- Availability of acceptable refrigerants

- Legal requirements for manufactures to take back waste based on the polluter pays principle

- Increased demand for materials that can be re-used or recycled (e.g. due to cost of landfill, LA targets, etc)

- Enhanced supply chain management towards sustainable procurement

- Greater demand for natural (little processed) sustainable materials

- Depletion of fossil fuels

- Restrictions on quarrying and dredging for aggregates

- Development, understanding and acceptance of Life Cycle Analysis (LCA)/costing as a useful and valid tool

- Pressures to use local sources to reduce transport impacts

Skills shortages (greatest potential constraint)

Less land available

(Source: BSRIA, 1999)

Anink et al. (1996) suggest that if sensible informed decisions are to be made with regards to the choice of materials then the professionals involved in the industry need guidance into the environmental impacts of the range of materials available to them. Reliable information and details of the environmental effects of building materials and certain technical operations are not readily or freely available (Anink et al. 1996). Up to now the environmental profiles of individual products and processes have mainly been identified by means of (LCA) Life Cycle Analysis studies, which map out the environmental effects of a particular material, from extraction through to production, use, demolition and recycling. However, there is already substantial agreement that LCA is not suitable for comparing choices in the design processes of buildings (Anink et al. 1996). This is probably related to the amount of time and resources it takes to complete a full LCA meaning that to compare materials in this way is cost ineffective. Moreover, most building products have not yet been investigated in this way. Further, these studies do not tell us how to evaluate one kind of environmental impact against another – for instance, what is more important (in the long and short-term), destruction of tropical rainforests or destruction of the ozone layer (Anink et al. 1996)?

This review presents a clear gap in the knowledge revolving around the use of sustainable materials in construction and paves the way for the research conducted in the following chapters.

## **3.0 Methodology**

### **3.1 Introduction**

This chapter outlines and justifies the research methodology employed in this thesis. The chapter provides an understanding of the theoretical foundation of the research and highlights the reasons for the selection of the research design. In doing so this will address the issues of validity, reliability and generalisability. The chapter then moves on to deliberate over the research design and implementation strategy considering the sampling strategy, data collection and data analysis methods. In conclusion the limitations of the research relevant during the writing of this thesis will be investigated.

### **3.2 Methodology**

There are many approaches by which research can be addressed. Broadly speaking these approaches can be viewed from two distinct philosophical positions. The first is Positivism, in which the properties of the research are to be studied through objective methods. The second is Phenomenology; this method is one where the researcher is involved in the research subject and study. Figure 6 below is from Easterby-Smith et al. (1991) and summarises the key differences between the positivist and phenomenological paradigms.

|                                   | <b>Positivist Paradigm</b>                                                                                                                                                                                                | <b>Phenomenological Paradigm</b>                                                                                                                                                                                            |
|-----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Basic Beliefs:</b>             | <ul style="list-style-type: none"> <li>• The world is external and objective</li> <li>• Observer is independent</li> <li>• Science is value free</li> </ul>                                                               | <ul style="list-style-type: none"> <li>• The world is socially constructed and subjective</li> <li>• Observer is part of what is observed</li> <li>• Science is driven by human interests</li> </ul>                        |
| <b>Researcher Should:</b>         | <ul style="list-style-type: none"> <li>• Focus on facts</li> <li>• Look for causality and fundamental laws</li> <li>• Reduce phenomena to simplest elements</li> <li>• Formulate hypotheses and then test them</li> </ul> | <ul style="list-style-type: none"> <li>• Focus on meanings</li> <li>• Try to understand what is happening</li> <li>• Look at the totality of each situation</li> <li>• Develop ideas through induction from data</li> </ul> |
| <b>Preferred Methods include:</b> | <ul style="list-style-type: none"> <li>• Operationalising concepts so that they can be measured</li> <li>• Taking large samples</li> </ul>                                                                                | <ul style="list-style-type: none"> <li>• Using multiple methods to establish different views of phenomena</li> <li>• Small samples investigated in depth over time</li> </ul>                                               |

Figure 6: Key features of positivist and phenomenological paradigms.

(Source: Easterby-Smith et al. 1991)

Although this table highlights the difference between the two research approaches

Easterby-Smith et al (1991) point out that the two paradigms are extremes and are thus

ideals that very rarely occur in their purest form within the realms of practical research. An approach that considers and employs both paradigms can be more beneficial in that it provides more perspectives regarding the subject matter than one method alone. With regards to the subject of the thesis, I feel that this method would benefit the research results and by looking at the issue of sustainable materials from questionnaires with suppliers and manufacturers, informal interviews within MWH and Trident West employees and the literature reviewed that the results achieved will truly arrive from multiple perspectives.

This approach is commonly known as triangulation which is defined by Robson et al. (1993) as "a method of finding out where something is by getting a 'fix' on it from two or more places".

From the information above I feel that a mixed method approach should be adopted for this research utilising elements from both the positivist and phenomenological approaches.

Robson et al. (1993) describes the method of grounded theory study as a method where "The central aim of the grounded theory study is to generate theory from data collected during the study". This strategy has been identified as being particularly useful in new, applied areas where there is a lack of theory and concepts to describe and explain what is going on (Robson, 1993) because I feel it can be cordially agreed that this description certainly applies to sustainability and how little detailed theory regarding it there presently is.

Crabtree and Miller have defined four types of qualitative (written or non-numerical) data analysis as described by Robson (1993). They are as follows:

- i) Quasi-Statistical methods
- ii) Template approaches
- iii) Editing approaches
- iv) Immersion approaches

These methods progress from more to less structured and formal in approach (Robson 1993). It is felt that the research regarding the sustainability of materials would benefit from one of these approaches more than the others. This is because of the broad and diverse nature of existing information in this field of research and highlights the need for a somewhat exploratory approach.

Editing approaches are less structured than the template approach and allow the researcher to be more interpretative and flexible with the use and analysis of the information collected (Robson, 1993). This approach also places far less emphasis on the use of predetermined categories to group information for analysis. The analysis of information is mainly based on the researcher's interpretation of the meanings and/or patterns drawn from the information collected. These are characteristics of grounded theory and I feel they seem suitable for the study of sustainability and more specifically corporate decision making in this context where the nature of this subject is relatively unexplored and lacks theoretical and experimental form.

### **3.3 Validity, Reliability & Generalisability**

There is a need for all of the research in this thesis to be considered trustworthy.

Robson (1993) highlights that it is not merely a case of conducting a good and thorough job, as pure intentions do not guarantee findings that attract notice. Easterby-Smith (1991) identifies that questions about validity, reliability and generalisability are as much

about philosophical viewpoint as they are about a specific methodology. Robson (1993) states that validity is concerned with whether findings are really about what they appear to be about or are they due to the effects of something else. He goes on to explain that generalisability refers to the extent to which research findings are more generally applicable, e.g. in other contexts, situations or times. He then further states that reliability refers to how we know that the results achieved are actually right or is their confusion or error.

I feel that because triangulation has been undertaken in accordance with relevant designs and methodologies, in addition to the convergence between widespread data sources, the methodology applied in this research should result in data that is valid, reliable and generalisable.

### **3.4 Research Design and Implementation**

The appropriate research methodologies having been selected, attention is now turned to the design and implementation of the research. The following section explains the choices relating to sampling strategies, data collection and data analysis.

#### **3.4.1 Sampling Strategy and Research Implementation**

The research begins with an extensive literature review, the subject of which is continued throughout the thesis. Chapter 8 incorporates the findings from the research conducted and the academic theories and arguments which support the case for the use of sustainable materials in the construction industry. These are presented to answer the research question "can construction projects be made more sustainable through the choice of materials used?"

### **3.5 Data Collection Methods**

Throughout the thesis a variety of approaches were used to try and explore the research question from a variety of perspectives. A summary of the methods used for each stage of the research can be found below.

#### **Literature Review**

A range of literature found in the public domain was used for the purposes of the research. Sources included academic journals, reports and literature relevant to the researched areas. The literature was read and then summarised in Chapter 2.

#### **Comparative Analysis**

A brief review of each of the three different environmental selection guides for choosing construction materials is included along with a comparison of the different guides and a critical analysis whereby any good or bad points will be described.

#### **Questionnaire with Suppliers**

A small telephoned questionnaire was issued to a number of suppliers within the Trident West Agreement for the purposes of finding out their current stance on sustainable materials. It is interesting to look here at suppliers who play a key role in the provision of materials to the Trident West and to see how their role must develop if construction projects are to become more sustainable through materials choice.

## **Interviews with MWH and Trident West Employees and Formulation of the Materials Matrix Tool**

A number of informal interviews were conducted when the opportunity arose, with participants at many levels in the Trident West Agreement. The interviews, with the exception of one semi-structured interview, allowed the researcher to follow many routes of enquiry, led by the interviewees and what they considered to be important in this area. From these interviews and in conjunction with information collected from the previous chapters the process of developing the Materials Matrix Tool was achieved in Chapter 6.

### **3.6 Limitations of Research**

Scandura and Williams (2000) state what many before have said, that "all research contains flaws, mainly down to the choice of method that will define what conclusions are reached".

Within this specific research project there are a number of issues that need highlighting as restrictions on the research investigation. The following few paragraphs highlight those areas that are known to be flawed and while the list is comprehensive it is by no means definitive.

The first limitation is realised in the literature review. I feel that sustainability by its very nature is a multidisciplinary subject that encompasses many different philosophies and subjects and despite the fact a large amount of material was read and reviewed it is impossible to read absolutely everything and encompass all opinions and theories that are in existence.

The data collected from the suppliers varied in its detail. It was sometimes answered in great detail or simply by Yes, or No, answers. It should be noted that one on one interviews would have captured more accurate data and would have resulted in answers that were relatively homogeneous and easy to compare. However this was not possible due to time and budget constraints.

It must also be noted that some of the suppliers are very aware of how important the Trident West Agreement is financially to them and may have given answers biased toward what MWH would 'like' to hear.

Finally the author realises that any exploratory piece of research is affected by subjective opinion. This is true in this case where the author's own subjective viewpoint is apparent throughout the research. Therefore any relevant considerations must be made by the reader as to the interpretation of results and in the conclusions at the end of the thesis.

## **4.0 Comparative Analysis of Environmental Resources for Selecting Construction Materials**

### **4.1 Introduction**

This chapter reviews and summarises three of the current methods of selecting construction materials in an environmentally responsible manner. As mentioned in the literature review there are currently very few tools or guidelines for selecting materials in an environmentally responsible way and any available guidelines, such as those for carrying out sustainable construction in the literature review, are useful for guiding efforts. MWH are interested in the informed choice of materials for construction in an attempt to make their construction projects more sustainable and a description of each of the three guides described here represent almost the complete range of environmental selection methods that are available in the public and construction domains.

The three methods to be looked at include:

- i) *The Green Guide to Specification*. This guide looks at different construction materials in various contexts and explores their potential environmental impacts.
- ii) *Green Building Handbook*. This guide looks at different groups of materials, e.g. different types of wall insulation, and the associated environmental risks associated with each one.

- iii) *Handbook of Sustainable Building*. This guide describes and utilises the Environmental Preference Method to enable people to choose the most environmentally friendly materials.

Each method will be described and examples of the guides themselves are included within the chapter. A short conclusion at the end of the chapter will highlight any potential benefits or disadvantages to these methods and how this information may be used by MWH in the construction of the materials selection tool for use by them and their clients.

## **4.2 The Green Guide to Specification**

The green guide to specification is described as an environmental profiling system for building materials and components and was co-authored by Oxford Brookes University, The Post Office Property Holdings, and the Building Research Establishment (BRE) and published in 1998.

The guide is an attempt to design a tool or guide for designers and engineers that is of practical value in making decisions about materials choice in construction projects in specific contexts, rather than endless boxes full of numbers that make the decision between construction materials no easier than normal. It is based on extensive numerical and quantitative data and measures relatively accurately the impacts of building materials with regard to embodied energy, emissions, toxicity, wastes, use of resources and recycling properties. Figure 7 overleaf expands upon these areas of concern that the guides' authors felt reflected the national opinion relating to the production of building materials used in the UK.

|                                  |                                                                                                                                                         |
|----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Toxic pollutants</b>          | arising from manufacturing and combustion                                                                                                               |
| <b>Primary energy used</b>       | in extraction, production and transport                                                                                                                 |
| <b>Emissions</b>                 | CO <sub>2</sub> NO <sub>x</sub> SO <sub>2</sub>                                                                                                         |
| <b>Resources</b>                 | Mineral resources<br>Water<br>Oil feedstock                                                                                                             |
| <b>Reserves of raw materials</b> |                                                                                                                                                         |
| <b>Wastes generated</b>          |                                                                                                                                                         |
| <b>Recycling</b>                 | % of recycled materials in finished product<br>% capable of being recycled in finished product<br>% currently recycled in UK energy required to recycle |

Figure 7: Material criteria used by the Green Guide.

The guide has taken the initiative to translate the data collected into what is described as “Simple environmental profiles to enable specifiers to make meaningful comparisons between materials and components” (BRE, 1998). The method employed in the profiles for each material follow a simple A, B, or C rating with A representing the least environmental impacts or best environmental performance. An example of this format can be seen in Figure 9.

Each material when presented in the profiles is entered in their as-built elemental form, which makes materials comparable on a one-on-one basis when doing a very similar job, e.g. UPVC or Wooden window frames. The guide points out that “A direct comparison between the Environmental Profile of one tonne of structural steel and one tonne of structural concrete would be misleading, as less steel is required to achieve the same structural performance” (BRE, 1998). This is an important point and highlights that this

guide offers comparable contexts for different materials which, I feel, results in meaningful data.

The guide itself is divided into three different sections; High-mass elements such as external walls, Medium-mass elements such as windows, and Low-mass materials like walling and roofing insulation. This is an attempt by the authors to allow the users of the guide to compare and contrast materials in a similar context rather than comparing the profiles of concrete and paint which would be meaningless (BRE, 1998).

#### **4.2.1 Methodology Used in the Green Guide to Specification**

The methodology in brief was established around "Specifications based on commonly found components, assemblies and materials but modified to reflect the best available data and provide a representative range of specifications" (BRE, 1998).

The methodology goes further to state that "each for each specification, the constituent materials, their relative quantities per M<sup>2</sup> and their expected life were estimated. The relevant published data were then located and compiled into a spreadsheet matrix". (BRE, 1998).

A final summary rating was subsequently determined in two stages for all of the materials. The first stage looks at the relative importance weighting assigned to each of the criteria in Figure 7 and these are summarised below in Figure 8. The second stage then looked at assigning each element of a profile sheet an A, B, or C, value that could be used to display the information, an example of which can be seen in Figure 9.

|                                                               |       |
|---------------------------------------------------------------|-------|
| • CO2 emissions                                               | 241.5 |
| • Primary energy used in extraction, production and transport | 72    |
| • Oil feedstock consumption                                   | 72    |
| • VOC & NOx emissions                                         | 56.5  |
| • % of recycled materials in finished product                 | 50.5  |
| • Toxic pollutants arising from manufacturing                 | 42    |
| • Water consumption                                           | 33.5  |
| • Wastes generated                                            | 32.5  |

Figure 8: Weightings used by BRE

|                       |                                | Pitched, ins, felt, battens and slates | Pitched, ins, felt, battens and clay tiles | Pitched, ins, felt, battens and concrete tiles | Pitched, ins, felt, battens and composition slates | Timber joists, ins, ply, mineralised felt | Timber joists, ins, ply, asphalt, chippings | PCC slab, ins, asphalt, chippings | PCC slab, ins, Polyester felt, chippings | In-situ 100 mm RC flat slab ins, asphalt, chippings | In-situ 100 mm RC flat slab ins, Polyester felt, chippings |
|-----------------------|--------------------------------|----------------------------------------|--------------------------------------------|------------------------------------------------|----------------------------------------------------|-------------------------------------------|---------------------------------------------|-----------------------------------|------------------------------------------|-----------------------------------------------------|------------------------------------------------------------|
| <b>Toxicity</b>       | in manufacturing               | A B C                                  | A B C                                      | A B C                                          | A B C                                              | A B C                                     | A B C                                       | A B C                             | A B C                                    | A B C                                               | A B C                                                      |
|                       | in combustion                  | A B C                                  | A B C                                      | A B C                                          | A B C                                              | A B C                                     | A B C                                       | A B C                             | A B C                                    | A B C                                               | A B C                                                      |
| <b>Primary energy</b> |                                | A B C                                  | A B C                                      | A B C                                          | A B C                                              | A B C                                     | A B C                                       | A B C                             | A B C                                    | A B C                                               | A B C                                                      |
| <b>Emissions</b>      | CO <sub>2</sub>                | A B C                                  | A B C                                      | A B C                                          | A B C                                              | A B C                                     | A B C                                       | A B C                             | A B C                                    | A B C                                               | A B C                                                      |
|                       | VOCs                           | A B C                                  | A B C                                      | A B C                                          | A B C                                              | A B C                                     | A B C                                       | A B C                             | A B C                                    | A B C                                               | A B C                                                      |
|                       | NO <sub>x</sub>                | A B C                                  | A B C                                      | A B C                                          | A B C                                              | A B C                                     | A B C                                       | A B C                             | A B C                                    | A B C                                               | A B C                                                      |
|                       | SO <sub>2</sub>                | A B C                                  | A B C                                      | A B C                                          | A B C                                              | A B C                                     | A B C                                       | A B C                             | A B C                                    | A B C                                               | A B C                                                      |
| <b>Resources</b>      | minerals                       | A B C                                  | A B C                                      | A B C                                          | A B C                                              | A B C                                     | A B C                                       | A B C                             | A B C                                    | A B C                                               | A B C                                                      |
|                       | water                          | A B C                                  | A B C                                      | A B C                                          | A B C                                              | A B C                                     | A B C                                       | A B C                             | A B C                                    | A B C                                               | A B C                                                      |
|                       | oil feedstock                  | A B C                                  | A B C                                      | A B C                                          | A B C                                              | A B C                                     | A B C                                       | A B C                             | A B C                                    | A B C                                               | A B C                                                      |
| <b>Reserves</b>       |                                | A B C                                  | A B C                                      | A B C                                          | A B C                                              | A B C                                     | A B C                                       | A B C                             | A B C                                    | A B C                                               | A B C                                                      |
| <b>Wastes</b>         | generated                      | A B C                                  | A B C                                      | A B C                                          | A B C                                              | A B C                                     | A B C                                       | A B C                             | A B C                                    | A B C                                               | A B C                                                      |
| <b>Recycling</b>      | % contained                    | A B C                                  | A B C                                      | A B C                                          | A B C                                              | A B C                                     | A B C                                       | A B C                             | A B C                                    | A B C                                               | A B C                                                      |
|                       | % capable of being             | A B C                                  | A B C                                      | A B C                                          | A B C                                              | A B C                                     | A B C                                       | A B C                             | A B C                                    | A B C                                               | A B C                                                      |
|                       | % currently recycled in UK     | A B C                                  | A B C                                      | A B C                                          | A B C                                              | A B C                                     | A B C                                       | A B C                             | A B C                                    | A B C                                               | A B C                                                      |
|                       | energy required to             | A B C                                  | A B C                                      | A B C                                          | A B C                                              | A B C                                     | A B C                                       | A B C                             | A B C                                    | A B C                                               | A B C                                                      |
| <b>Summary rating</b> |                                | A B C                                  | A B C                                      | A B C                                          | A B C                                              | A B C                                     | A B C                                       | A B C                             | A B C                                    | A B C                                               | A B C                                                      |
|                       | cost range (£/m <sup>2</sup> ) | 67-89                                  | 67-77                                      | 47-63                                          | 55-69                                              | 51-64                                     | 48-70                                       | 60-85                             | 64-75                                    | 66-87                                               | 63-84                                                      |
|                       | replacement interval (yrs)     | 60                                     | 60                                         | 60                                             | 60                                                 | 15                                        | 20                                          | 20                                | 20                                       | 20                                                  | 20                                                         |

Figure 9: BRE Green Guide Profile Sheet for choosing roofing materials

#### **4.2.2 Summary of the Green Guide to Specification**

The Green Guide to Specification provides a comprehensive range of profile sheets that are commendable in their realisation that the use and impacts of materials is an extremely context specific issue. For example, the impacts of steel in a sub-frame of a building may be completely different to that of steel that is used for door handles.

The profile sheets provide a useful tool for designers, engineers and architects that allows them to make easy comparisons between different materials for the same job without the complication of large sets of incomprehensible data.

This guide provides a useful contribution toward answering the research question and although it looks predominantly at the environmental aspects of materials, several of the criteria including those to do with recycling factors and waste potential have been earmarked for use in the Materials Matrix in Chapter 6.

#### **4.3 The Green Building Handbook**

The Green Building Handbook is a guide to building products and their impact on the environment, published in 1997. The handbook is the product of the first twelve issues of the Green Building Digest, which was first published in 1995 in an attempt to distribute information about the environmental impact of building materials and techniques (Woolley, 1997).

The handbook begins with an introduction concerning green building that it defines by saying:

“A green approach to the built environment involves a holistic approach to the design of buildings; that all the resources that go into a building, be they materials, fuels

or the contribution of the users need to be considered if a sustainable architecture is to be produced”.

(Vale and Vale (From Woolley, 1997)).

The handbook describes green building as a complex process and four major principles of green building have been earmarked to make it easier to understand. These are shown below:

- i) Reducing energy in use
- ii) Reducing embodied energy and resource depletion
- iii) Minimising external pollution and environmental damage
- iv) Minimising internal pollution and damage to health

The handbook uses these four guiding principles to design a methodology that provides a useful tool for designers, engineers, architects and anyone else making decisions regarding the choice of construction materials.

#### **4.3.1 The Green Building Handbook Methodology**

The handbook comments that it “does not try to offer a simplistic and easy set of conclusions because any serious eco-designer would not use it in this way” (Woolley, 1997). It instead provides a display of already known information and allows the materials selector to come to their own conclusions regarding which material choice is the most environmentally friendly in a particular context.

The methodology looks at both issues concerning the production of a material as well as those potential implications in its use. A comprehensive list of factors in the handbook is shown below in Figure 10.

The methodology uses a Lifecycle thinking approach whereby a product or materials extraction, production and distribution are considered in the 'production' phase. The product or materials use and disposal, the final stages of their lifecycle, are included under the 'use' heading. This guide also first considers the economic cost of each material, the unit price multiplier. This consideration of the economic aspect of sustainability is important when looking at the overall sustainability of materials and this criteria will be used in the Materials Matrix in Chapter 6.

| Production Factors                  | Use Factors              |
|-------------------------------------|--------------------------|
| Energy Use                          | Energy Use               |
| Resource Depletion (Biological)     | Durability/Maintenance   |
| Resource Depletion (non-Biological) | Recycling/Reuse/Disposal |
| Global Warming                      | Health Hazards           |
| Ozone Depletion                     | Other                    |
| Toxics                              |                          |
| Acid Rain                           |                          |
| Photochemical Oxidants              |                          |
| Other                               |                          |

Figure 10: Factors for consideration materials impacts (From Woolley, 1997)

Each of the products or materials rated on one of the Handbooks tables is graded on its perceived impact in each of the areas named in Figure 10 above. A system of different sized circles ranging from large to none (see Figure 11 below) is used with a large circle representing a large or worst environmental impact and no circle relating to no significant impact at all. The methodology states that "Marks on each table will only indicate poor records relative to other products on the same table".

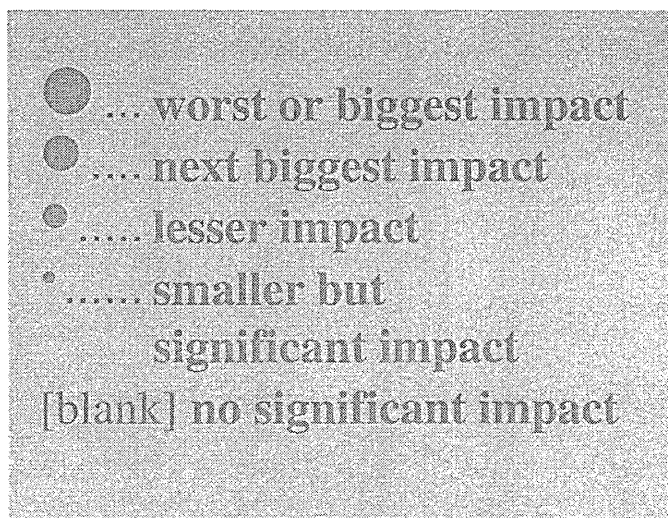


Figure 11: Grading of impacts (Source Woolley, 1997).

This page shows Figure 12, an example of one of the guidance sheets in the Green Building Handbook for use in selecting masonry materials.

|                          | £                     | Production |                          |                              |                |                 |        |           |                        |       |            | Use                    |                          |        |       |            |  |
|--------------------------|-----------------------|------------|--------------------------|------------------------------|----------------|-----------------|--------|-----------|------------------------|-------|------------|------------------------|--------------------------|--------|-------|------------|--|
|                          | Unit Price Multiplier | Energy Use | Resource Depletion (bio) | Resource Depletion (non-bio) | Global Warming | Ozone Depletion | Toxics | Acid Rain | Photochemical Oxidants | Other | Energy Use | Durability/Maintenance | Recycling/Reuse/Disposal | Health | Other | ALERT!     |  |
| Bricks                   |                       |            |                          |                              |                |                 |        |           |                        |       |            |                        |                          |        |       |            |  |
| Ordinary Clay            | 1.0                   | ●          |                          |                              |                |                 | ●      | ●         | ●                      | ●     |            |                        |                          |        |       |            |  |
| Flettons                 | 0.8                   | •          |                          |                              |                |                 | ●      | ●         | •                      | ●     |            |                        |                          |        |       |            |  |
| Soft Mud/Stocks          | 1.0                   | ●          |                          |                              |                |                 | ●      | ●         | ●                      | ●     |            |                        |                          |        |       |            |  |
| Perforated Clay          | 1.0                   | ●          |                          |                              |                |                 | •      | •         | ●                      | •     |            |                        |                          |        |       |            |  |
| Calcium-Silicate         | 0.9                   | ●          |                          | ●                            | ●              |                 | ●      | ●         | ●                      | ●     |            |                        |                          |        |       |            |  |
| Re-Used                  | 1.4                   |            |                          |                              |                |                 |        |           |                        |       |            |                        |                          |        |       |            |  |
| Concrete Blocks          |                       |            |                          |                              |                |                 |        |           |                        |       |            |                        |                          |        |       |            |  |
| Ordinary Dense Blocks    | 0.3                   | ●          | •                        | ●                            | ●              |                 | ●      | ●         | ●                      | ●     |            |                        |                          |        |       |            |  |
| Lightweight Aggregate    | ?                     | ●          | •                        | ●                            | ●              |                 | ●      | ●         | ●                      | ●     |            |                        |                          | ●      |       |            |  |
| Aerated                  | 3.2                   | ●          | •                        | •                            | •              |                 | ●      | ●         | ●                      | ●     |            |                        |                          |        |       |            |  |
| Composite Insulating     | 1.4                   | ●          | •                        | ●                            | ●              | ●               | ●      | ●         | ●                      | ●     |            |                        |                          |        |       | CFCs?      |  |
| Stone                    |                       |            |                          |                              |                |                 |        |           |                        |       |            |                        |                          |        |       |            |  |
| Local                    | 3.2                   |            |                          |                              |                |                 |        |           |                        | •     |            |                        |                          |        |       |            |  |
| Imported                 | ?                     | ●          |                          |                              |                |                 |        |           |                        | ●     |            |                        |                          |        |       |            |  |
| Reclaimed                | 3.2                   |            |                          |                              |                |                 |        |           |                        |       |            |                        |                          |        |       |            |  |
| Artificial               | 1.4                   | ●          | •                        | ●                            | ●              |                 | ●      | ●         | ●                      | ●     |            |                        |                          |        |       |            |  |
| Mortar Ingredients       |                       |            |                          |                              |                |                 |        |           |                        |       |            |                        |                          |        |       |            |  |
| Ordinary Portland Cement | n/a                   | ●          |                          | •                            | ●              |                 | ●      | ●         | ●                      | ●     |            |                        | •                        | ●      |       | Haz. Waste |  |
| Pure Lime                | n/a                   | ●          |                          | •                            |                |                 | ●      | ●         | •                      | ●     |            |                        |                          | ●      |       |            |  |
| Hydraulic Lime           | n/a                   | ●          |                          | •                            | ●              |                 | ●      | ●         | •                      | ●     |            |                        |                          | ●      |       |            |  |
| OP Blastfurnace Cement   | n/a                   | ●          |                          | •                            | ●              |                 | •      | •         | •                      | •     |            |                        | •                        | ●      |       |            |  |
| OP Pulverised Fuel Ash   | n/a                   | ●          |                          | •                            | ●              |                 | ●      | •         | •                      | •     |            |                        | •                        | ●      |       |            |  |
| Masonry Cement           | n/a                   | ●          |                          | •                            | ●              |                 | ●      | •         | •                      | ●     |            |                        | •                        | •      |       |            |  |
| Sand and Gravel          | n/a                   |            | •                        | ●                            |                |                 |        |           |                        | ●     |            |                        |                          |        |       |            |  |

Figure 12: Example guide sheet for masonry materials (Source Woolley, 1997)

### **4.3.2 Summary of Green Building Handbook**

The Green Building Handbook represents a lot of information collated together into one book which is a useful aid to any designer or engineer choosing building materials. The way the information is displayed facilitates ease of use and each chapter in the book relates to a different area including insulation materials, masonry, window frames and roofing materials. Each chapter consists of a product table like the one above (Figure 12) and then accompanying details of why each product scored how it did for each component. The depiction of the information also allows the user to choose quickly between different materials for the same job based on their different environmental impacts.

The most beneficial aspect of this guide in relation to the research work is the method of using lifecycle thinking to assess materials in addition to several of the criteria in Figure 10. The issues of cost, energy use, ozone depletion from the production phase were highlighted by both myself and through conversations with MWH staff for possible use in the matrix in Chapter 6. Similarly the criteria from the use phase that would be used later in the research included durability and maintenance and recycling factors.

### **4.4 The Handbook of Sustainable Building**

This book is based upon an Environmental Preference Method (EPM) for the selection of materials for use in construction and refurbishment. It was published by James and James in the UK in 1996 and based on work that was originally conducted in the Netherlands in the early 1990's. It was developed "in order to enable design teams to select materials or products that have a reduced impact on the environment compared to similar items performing the same function" (Anink et al. 1996 from EU directory). It

was originally conceived to target the domestic building sector but was rapidly made applicable to cover all types of buildings and structures.

The Environmental Preference Method (EPM) has been a very successful tool in the Netherlands and over 50% of local Dutch authorities use the original Dutch version of the handbook to aid in drawing up building and construction guidelines (Anink et al. 1996).

Similarly to the Green Building Handbook the EPM attempts to consider environmental impacts throughout the whole lifecycle of a material or product. This includes materials extraction, materials processing, manufacture, use and finally the decomposition phase (Simon et al. 1998).

The book itself is written in four different sections. The first is based around the principles of sustainable buildings, the second is an explanation of the EPM in detail and the third looks at the actual environmental selection of materials in construction in addition to the refurbishment of buildings. Finally the last section of the book looks at construction materials themselves and provides technical and general information about them.

#### **4.4.1 EPM Methodology**

The EPM is a method of comparing materials and products that are currently available and subsequently ranking them on the basis of their environmental impacts.

The EPM, as mentioned in 4.4, looks at the entire lifecycle of a material from cradle to grave or from extraction to decommissioning. Yet it simplifies the process from that of a Lifecycle Analysis (LCA) and merely looks at the issue from a lifecycle thinking perspective rather than using many complex equations and data sets. The EPM looks at

a number of issues, which are perceived by the authors to be the most relevant and important. These, are listed below:

- i) Shortage of raw materials
- ii) Ecological damage caused by extraction of raw materials
- iii) Energy consumption at all stages (including transport)
- iv) Water consumption
- v) Noise and odour pollution
- vi) Harmful emissions, such as those leading to ozone depletion
- vii) Global warming and acid rain
- viii) Health aspects
- ix) Risk of disasters
- x) Repairability
- xi) Reusability
- xii) Waste

(Source Anink et al. 1996)

The methodology realises that the EPM is not static and that the handbook itself was collated from information that was available at the time of going to press. It stands to reason that any new data from research has the potential to affect the Environmental Preferences and therefore the handbook itself (Anink et al. 1996).

The assessment procedure of the EPM for each construction material or product includes the same four stages as LCA (Anink et al. 1996), that is Goal definition, Inventory, Classification and Evaluation. The results from these procedures are then presented in the form of a selection box as shown in Figure 13 shown below. The option on the left is

always the best with environmental preference, and the option on the far right is those materials that are not recommended in the slightest.

Figure 13 below shows an example of the EPM selection guide used in selecting the material for ground under suspended floors.

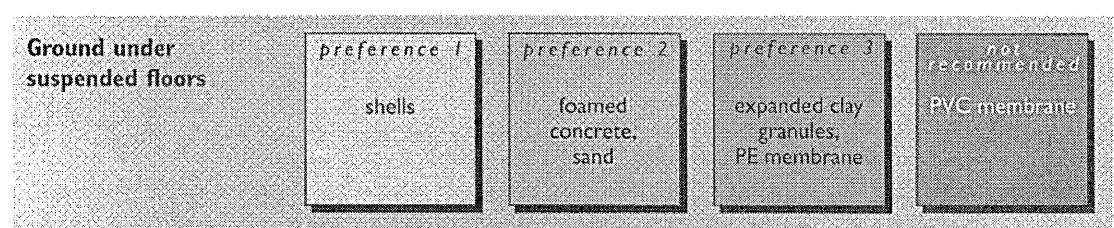


Figure 13: Example of EPM material selection tool (Source: Anink et al 1996)

#### 4.4.2 Summary of the EPM

The EPM is relatively simple to use, as it is a tool that suggests which material is environmentally preferable over another in a certain situation. The EPM although widely used across the Netherlands and much of Europe is the oldest and most simple of the methods in this chapter. It only supplies a limited number of options for each building task and designers and engineers may feel the need to have both more choices and more information regarding those choices.

Its strengths lie in the ease of use and the large number of scenarios catered for in the book. However, as with all the other resources it is only a book and not a dynamic resource and as such the information can be outdated. The number of criteria considered is also quite high and incorporates a range of environmental and some social factors.

Criteria of interest here include noise and odour pollution in addition to water consumption. Again these were identified through conversations between MWH and myself for use in the materials matrix in Chapter 6.

#### **4.5 Comparative Analysis of Construction Material Selection Methods**

Of the three methodologies none fully deals with the aspects of sustainability in total.

The BRE Green Guide looks at a range of environmental factors and also considers the unit cost of materials but very little direct social issues. The Green Handbook by Woolley et al (1997) is very strong in its environmental criteria and also considers the economic cost of materials reflecting the economic dimension of sustainability. The Green Handbook also takes the initiative to include potential health hazards and therefore some social dimension of the sustainability dilemma. The EPM is the oldest of the three methodologies for selecting materials and is referred to as the sustainable building handbook. It is quite advanced in its comprehensive consideration of environmental issues and also considers human health, and odour and noise pollution, which are both social aspects of sustainability. It does however neglect the economic side of sustainability and is based around an environmental preference method only.

The three resources reviewed in Chapter 4 represent the major sources of literature available publicly concerning the subject of selecting materials for use in construction in a way that considers the environment. The three books all provide guidance for designers and engineers, or whoever is making the decision about what materials to purchase for a construction project and allows them to make decisions regarding which materials they choose on the basis of factors other than the main consideration of cost. In doing so they are increasing the opportunity to reduce environmental and social impacts before they have even occurred. All three of the guidance methods however look predominantly at environmental factors, with only minor economic and social elements in their guidelines. I feel they emphasise the need for a sustainable materials selection method that could be of value to the construction industry and consequently of

high value to MWH and the Trident West Agreement. They would subsequently help to achieve increased sustainability of their projects through informed materials choice.

The guidelines and different criteria within the books have not only provided an insight into a potential sustainable materials selection method but a starting point for one too.

Some of the factors have been adapted to fit into the Materials Matrix in Chapter 6 and where it was felt economic and social considerations have been missing in the guides they have been supplemented using the three domains of sustainability.

The three guides themselves are also all relatively old, all published between 1996 and 1998 and are based on research results that are even older. This highlights the need for new information within the construction industry, which is a huge sector globally, to make more informed decisions regarding materials choice and that regular updates to such information is necessary to stay abreast of all current and future economic, environmental and social issues relating to the industry and its sustainability.

The guidebooks played an important role in the realisation that it is the individuals that choose materials in construction projects that have one of the greatest potentials to reduce impacts through the decisions they make about materials choice in construction. It can be recognised that by providing these key individuals in an organisation, such as Trident West, with the information and resources they need to choose more sustainable materials then they can be perceived as making the construction industry more sustainable through the choice of materials they make.

The guides in Chapter 4 also draw attention to the issue of ranking and weighting different criteria. Of the three guides only the Green Guide to Specification (BRE, 1998) attempts to tackle this issue, (see Figure 8) and try to prioritise one impact over another. I feel that this approach is not going to be an easy one without the aid of

complex data sets and to some extent involves a high degree of subjectivity on the part of the designer of any materials selection guide. Woolley in the Green Handbook quite rightly states though that "The balancing of different factors is a political rather than scientific matter" (Woolley et al. 1997). It can be concluded that by trying to establish complex equations or sums to work out which of the environmental factors is more important than others is a difficult and time consuming task that will also bear considerable subjective viewpoints by the author.

The decision to not rank or weight different criteria was a major consideration that was taken on board for the development of the Materials Matrix in Chapter 6 as it was felt that people would place too much emphasis on selecting materials just to satisfy the main criteria. For a truly sustainable approach MWH and myself decided that it was more beneficial to allow all potential assessment criteria to be on an even scale and no one criteria would be perceived as more important than the others unless specifically determined in a design brief, e.g. picking the material that cost the least or has a high recycled content.

One other finding from this stage of the research that was incorporated into the Materials Matrix was the idea of lifecycle thinking used in both the Green Building Handbook (Woolley, 1997) and in the Handbook of Sustainable Building (Anink et al, 1996) and considers the environmental impacts throughout the whole lifecycle of a material. This is a useful idea that can be applied to the sustainability of a material and the different stages of its lifecycle, extraction, manufacture, installation, use and decommissioning and a concept which was used in the development of the Materials Matrix in Chapter 6.

In summary this section of the research has highlighted the usefulness of guides to designers to assist and inform them in their choices of materials in a practical fashion emphasising the need for a more sustainable method for materials selection. It also drew attention to the fact that even if designers and engineers do specify the use of more sustainable materials, they are not available from suppliers or manufacturers then it is not possible to use them and subsequently construction projects will be less sustainable in their use of materials.

One other major finding from this section of the research regards the contextual considerations when looking at information regarding the impacts of materials. Much of the information reviewed in the guides is very specific in its nature and the figures displayed often represent a specific material in a specific context.

The next chapter looks at the other major issue with regard to the increased sustainability of construction projects within MWH, the suppliers. Their current situation regarding sustainability is explored in addition to the results gathered from the questionnaire that was generated.

## **5.0 Suppliers and Materials in Relation to the Trident West Agreement**

### **5.1 Introduction**

The current situation regarding suppliers of construction materials to the Trident West Agreement is explored in addition to the introduction of the concept of sustainable materials procurement. This chapter looks at the current design processes in MWH for projects within the Trident West Agreement and considers how materials procurement operates. It also includes the results and analysis from questionnaires from four of the suppliers to the Trident West Agreement and their social and environmental activities with regard to the materials they supply to the agreement.

The situation regarding suppliers and their attitudes and actions toward sustainability is particularly important in relation to the research question. Construction projects carried out by MWH, including those within the Trident West Agreement, cannot use more sustainable materials on their projects if they are unavailable because suppliers and manufacturers are unaware of the concept of sustainability.

### **5.2 Trident West Agreement and Suppliers**

Within the Trident West Agreement there are specific factors influencing the supply of materials. The water company plc involved in the agreement has a lot of purchasing power due to their large scale of operations both within and outside of the Trident Agreement. During the Asset Management Plans (AMP's) that take place every 5 years, a process of auctioneering and tendering for suppliers occurs at a strategic level. This occurs two years prior to the new AMP. I feel that even now this in itself presents a

barrier to sustainability as it highlights that for any opportunity to get new suppliers and manufacturers that believe in sustainability involved in Trident West, it would be impossible for them to supply materials until the next AMP period begins. The alliance then selects a number of suppliers to operate within the Trident West over the next AMP. It is from this framework of suppliers that any materials required in any of the projects must be selected or purchased. The suppliers are chosen primarily on the basis of how low their costs and prices, in addition to their perceived level of quality and any previous supply arrangements to the Trident Agreement. The added attraction at this stage of the proceedings for the water plc is that for using the same framework of suppliers throughout all of its operations, and therefore buying considerable quantities of materials from a few select suppliers over a five year period, it receives substantial financial discounts.

### **5.3 Materials Selection Within Trident West Projects**

Once the supplier framework is set up for an upcoming AMP then any subsequent material requisites will all be procured from these sources.

With regards to the specific selection of materials for a project, this choice is made by one of two groups of people within the Trident West Agreement. Design engineers at the design stage of a project specify the materials required for individual products e.g. water tanks or pipelines before the commencement of any construction activities.

Alternatively they are selected by a site manager (MWH Interview, Appendix 2) who, when on site at any installation, will order any equipment needed in the construction phase e.g. wood and bricks, when it is needed.

With decisions made at a strategic level regarding construction materials procurement for fixed five-year periods during the AMP's, it is more difficult to strive to make construction projects more sustainable through materials choices because of the inability to respond to new, more sustainable materials and suppliers.

A meeting with the chief design engineer from MWH within the Trident West Agreement at Reading (See Appendix B) drew emphasis toward particular types of projects that are more likely to benefit, and be seen as more sustainable, from an improvement through informed material choices. The meeting yielded that water pipelines closely followed by water tanks and chambers have the largest potential to become more sustainable due to the large number of projects that involve these elements. The six different elements shown below are those factors highlighted by MWH that show potential for improvements in sustainability through materials choice. They are ranked in order of priority after the meeting with the chief design engineer:

- i) Pipelines
- ii) Tanks and Chambers
- iii) Plant/Equipment
- iv) Buildings/Enclosures
- v) Electrical
- vi) Infrastructure

(Source: Appendix B)

Following further consultation at MWH it was decided to focus on both the pipelines as well as tanks and chambers used by Trident West as they had the greatest potential to see a benefit from the more informed choice of materials. After some deliberation it was

decided to choose one of these issues that would provide a context for looking at the sustainability of materials in a particular context. The details surrounding both of the issues are summarised below:

## **Pipelines**

The pipelines used in Trident West's projects are relatively homogeneous in size and shape and they are used in the majority of installations even if often only in short 200-300m lengths. The majority of these pipelines are made from Polyvinylchloride (PVC) or Polyethylene (PE) but a range of materials including ductile iron and concrete is also used. The pipelines represent a very small financial input by Trident West and ranked sixth overall in economic impact.

## **ii) Tanks and Chambers**

The tanks and chambers again represent one of the most numerous structures constructed by Trident West. They are usually constructed from steel or concrete but also on occasions Glass Reinforced Plastic (GRP). These units can be constructed for use both above and below ground. The chief design engineer points out that some of the tanks and chambers, albeit a very small number, are made out of substitute materials such as brick and that some ash is used in the concrete as a mixer too. This represents a small concentrated effort by Trident West already looking at ways to improve the sustainability of their materials unrelated to this work. This area represents the greatest financial input by Trident West and ranks number one out of the six construction elements.

Following careful deliberation within MWH it was decided to go ahead and use the pipelines as the context for exploring potential sustainable materials. This decision arose primarily through cost factors and that pipelines by far had the smallest economic impact of all the construction elements. Conversely the tanks and chambers represented the biggest financial impact and as such it was viewed as beneficial to try out any exploratory work on pipelines first and any failures encountered could be eradicated before new ideas were then transferred to tanks and chambers.

#### **5.4 Potential Issues Arising from Materials Supply and Selection Situation in Trident West**

Following the meetings with the chief design engineer in addition to liaising with another lead design engineer, time was taken within MWH to decide on the best course of action to endeavour to make their construction projects at MWH more sustainable through the materials used. The Head of Sustainable Development Europe at MWH, also a Visiting Professor at Cambridge University, had already highlighted that the context materials were used in was important. Now that pipelines had been selected for this purpose it was necessary to take the process of enquiry a step further forward.

It was determined within MWH that comments by the Lead Design Engineer and Site Manager regarding the lack of information regarding materials, with regard to their sustainability, should be addressed and that some kind of tool or set of guidelines would be very beneficial. The basis for this belief followed when the Lead Design Engineer revealed that sometimes choices between two materials had to be made at the design stage of a project and that when both materials met the required technical specification, e.g. the ability of a pipe to deal with a certain flow rate of water, then it was often up to

the Lead Design Engineer or any of the other senior engineers to make the decision based on personal preference, cost permitting of course. MWH concluded that it would be beneficial to explore this opportunity and that some kind of sustainable materials selection tool should be researched for potential application into the Trident West design process to increase the sustainability of future Trident West Agreement projects. The second major issue arising from preliminary research was that even if designers and engineers are assisted with a tool for choosing more sustainable materials they are limited in the number of suppliers of materials that they can choose from. Discussion within MWH led to the author's suggestion that framework suppliers for the Trident West Agreement could be subject to a pilot questionnaire. The idea with this questionnaire would be to assess specifically the materials that the framework suppliers supply to the Trident West Agreement. Having now decided to focus exclusively on pipelines the conclusion was reached to contact five framework suppliers and question them regarding the specific pipeline materials. An attempt was to be made to try and assess suppliers' current understanding of sustainability issues and how sustainable the materials supplied were.

## **5.5 Supplier Questionnaire Design**

Five framework suppliers were seen by MWH as an acceptable number to try out a pilot questionnaire with. The questionnaires were designed in conjunction with the Materials Matrix tool for engineers and designers in the next chapter and the subjects regarding the questions are examined there along with a more detailed explanation of the subject matter for each question. The questions were designed to include both specific materials issues relating to pipeline materials in addition to some more general questions

regarding company practices. It was realised early on in the research that an analysis of social sustainability for materials is relatively intangible and that environmental sustainability issues are far more prevalent in the literature. It was decided that a few questions regarding company attitudes towards sustainability were necessary to work out if the company was at all proactive in this area and to provide a broad framework of opinion for the questions themselves. However a separate questionnaire was developed with the water company plc to question these suppliers at a more strategic level regarding their social, economic and environmental sustainability but was to be kept separate from this research at the request of MWH.

## **5.6 Supplier Questionnaire Sample**

Below is a list of the twelve questions posed, concerning potential sustainable materials issues for suppliers and/or manufacturers, within the Trident West Agreement. The questions evolved from a combination of factors including the interview in Appendix B and those areas already highlighted in Chapter 4 from the guides. In addition to this, MWH requested that some issues, such as noise and odour, be included as they are issues they consider normally in all their projects and programmes.

In summary, questions 1 through to 5 and 9 and 10 look at materials specific issues, whilst questions 6, 7 and 8 are more general in their nature.

- i) Do you take into account the amount of embodied energy involved in the process of extracting and producing the materials you manufacture?
- ii) Do the materials you manufacture have a recommended or expected life span (how durable are they)? If so please answer with regard to materials you provide Trident West with.
- iii) The next question regards the recycling factors of the materials:
  - a) Do you incorporate recycled content into the materials you manufacture? e.g. aluminium % recycled content.
  - b) What percentage of the material is potentially recoverable at the end of its intended use? e.g. concrete is low, aluminium is high.
  - c) Are you aware of the energy required to recycle the materials at the end of their functional life? e.g. glass is energy intensive.
- iv) If details are not known about the potential recyclability of the materials, are you aware of their waste potential? For example, is the material intended to be discarded at the end of its functional life? (100% waste potential = very unsustainable).

- v) Is the amount of water used in the processing of the material calculated? What is the source of the water supply? (e.g. abstraction, greywater, pipeline etc.)
- vi) Do you have a biodiversity plan (or some sort of management) in place?  
If yes, can you please provide a copy?
- vii) Do you use any CFC's or any other known gases that are detrimental to the ozone layer?
- viii) Do you have a waste minimisation strategy in place? If yes, please provide a copy.
- ix) Do you apply the principles of sustainability (e.g. reduction of raw materials, minimisation of energy use) into your design procedures?
- x) Do you minimise noise and odour pollution in your production processes?  
Please give examples.
- xi) Do you record the origin of your materials, e.g. world, Europe, UK, local?
- xii) Are your materials easily repairable, e.g. section of pipes or is it less repairable and more replaceable, e.g. brittle plastics.

## **5.7 Summary of Results**

Having identified that designers and engineers require good quality tools to make informed decisions about the materials they use I now move on to the issue of suppliers of materials and the role they play in this research. The questionnaire developed by MWH and myself served to cause much interest amongst suppliers to the Trident West Agreement relating to their materials and how sustainable they are. The range of twelve questions was designed to investigate the current state of affairs within suppliers and manufacturers to the Trident West Agreement, in both company level attitudes and more specifically materials issues. The questions pulled out interesting results that ranged from some companies knowing very little about the concept of sustainability and sustainable materials through to one respondent who commented that these questions could not be given quick answers and that time on the part of their company was needed to answer them thoroughly.

The results from the four questionnaires are now discussed below and are divided into two sections. Firstly, the more generic sustainability questions and their answers are discussed with the materials specific issues results explained afterwards.

The questions regarding the attitudes of suppliers and manufacturers to sustainability at a company level received mixed responses. Of all the companies questioned none had a biodiversity plan or consideration within their organisation but several commented that they had comprehensive environmental policies or environmental committees where such issues could be targeted if necessary. Conversely all of the companies interviewed stated that they subscribed to zero use of CFC gases in their production processes. One such example states that "emissions analysis is part of our environmental assessment" the main motivation behind this being the UK's subscription to the Montreal Protocol

(Titenberg, 1998) and the subsequent targets set for UK industry by the government. Waste Management strategies showed less cohesion among all the companies and some subscribed to having full waste management strategies whilst others only operated on traditional principles of trying to be careful about the amount of waste produced. An example of this from one of the answer sheets in Appendix A states that "we try to reduce waste through the basic aim that waste is bad, but no specific strategy exists." The questions that looked more directly at the materials that manufacturers and suppliers supply the Trident West Agreement with returned some results that identified potential areas to improve the sustainability of materials supplied to Trident West. Only one company looked at measuring the embodied energy values of their materials. This is a vital strategy in looking at the reduction of energy consumption that is currently unacceptable as highlighted in the literature review in Chapter 2. More companies that supply materials to the Trident West Agreement should subscribe to such methods and MWH and the Trident West Agreement have the power to encourage this by asking that their suppliers do so. Question 3A, regarding the use or recycled content in building materials, raised interesting points from most of the companies surveyed as they all stated that there was some kind of industry standard that prohibited the use of recycled content in pipeline sections but that this standard may be under review very soon. I have been unable to find details of this standard in the time frame of the research but it is an area for concern which Trident West should certainly look at and is currently blocking the increased sustainability of construction materials available to them. Another potential area for improvement arose from Question 9 asking if companies record the origin of their materials. Local sourcing of materials is one of the potentially greatest contributors to sustainability as outlined in Section 2.5 of the literature review

as defined by CIRIA in their report on the construction industry and sustainability (CIRIA, 2001). Here the respondents showed a relative level of achievement in this area and most companies were happy to comment that they sourced the majority of their materials from UK based locations and those that didn't came from reputable sources or through their quality assurance department. This appeared to be an issue all of the suppliers performed well on, one which I recommend MWH and Trident West encourage as much as possible.

The final area that is highlighted as a potential problem for the increased sustainability of materials arises from Question 10 in the questionnaire and looks at the repairability of the pipelines used by Trident West. General comments from the respondents highlighted that damaged pipeline sections were nearly always replaced rather than repaired and one manufacturer commented that this again was due to industry standards whilst another stated that only when a client requested a section of pipeline was repaired rather than replaced would it be carried out. It can be recommended that Trident West investigate this as an issue and that in accordance with the UK waste management strategy, Reduce, Reuse, Recycle (Woolley QC, 2000) a repair is actively reducing the amount of materials needed to solve the problem as long as the repair can be completed to satisfactory industry standards.

The role of suppliers and manufacturers of construction materials should not be underestimated in terms of their potential contribution towards using sustainable materials in the construction industry and indeed within the Trident West Agreement. Suppliers and manufacturers are important in two main ways to this issue of sustainable materials; firstly, without their prior consultation they may be unaware of the implications of sustainability as some of the respondents in the questionnaires were. If

unaware and uneducated about sustainability how can suppliers' manufacturers of materials to the Trident West Agreement offer materials that are more or less sustainable. Secondly, if construction companies and organisations, like the Trident West Agreement, do not request that their suppliers and manufacturers offer and use sustainable materials or products then there is little or no motivation for these companies to act on their own without encouragement.

These two factors indicate that the way forward is for suppliers and manufacturers to co-operate and work together in partnership with one another to develop the use and procurement of more sustainable materials. This is a major point for consideration within Trident West where a more unified approach to the problem of making construction projects more sustainable through materials choice could see faster and more commendable moves toward sustainability in the construction industry.

The information from the questionnaire results was also a valuable source of information when filling in some sections of the Materials Matrix. Particular examples here include the use of information from both concrete and plastic pipeline manufacturers that allowed the Materials Matrix to be filled in using data that was highly specific to the context of Trident West. If more data of this quality and context had been available the Matrix would have been easier to fill out and would have had more relevance as a specific design tool for Trident West and MWH employees.

## **5.8 Conclusions**

From the questionnaires above some brief conclusions can be made in relation to the research question in the introduction.

Various respondents to the questionnaire took it in differing levels of seriousness, regarding both the subject matter and the Trident West Agreement itself. I felt that there were two main reasons for this. Some companies genuinely take the issue of sustainability very seriously and took more time over their responses to the questions even asking for them to be e-mailed to them rather than giving answers over the phone. Others though stated that the Trident West Agreement was a very important contract to them financially and I got the impression that maybe some answers supplied could have been aimed at providing the answers that MWH and the Trident West Agreement wanted to hear.

I also feel that MWH and Trident West should work with their suppliers and encourage them to embrace sustainability more comprehensively. Suppliers that perform better in such issues should be used as examples for other suppliers but an effort must be made not to exclude those suppliers that show worse performance on the basis of the answers received to the questions, rather they should be encouraged to conform to new sustainable methods of business practice and materials supply. This would have the added affect of moving sustainability up the supply chain and the potential supply of more sustainable materials could be expanded greatly and hence aid this research in its aim to make construction projects more sustainable through increased sustainable materials choice and use.

An interesting situation now exists surrounding the AMP timescale within Trident West and the way in which materials suppliers and manufacturers are tendered for. Currently the AMP's run for five years and this strategic level decision could affect the potential use of sustainable materials in construction. It may not be possible for this scheme to change but I would recommend that it is either reviewed by Trident West to allow

suppliers to be drafted in and out of the supplier agreement during this five year period or that if the current AMP must be completed under the current set of conditions it reviews this practice at the earliest possible stage.

On a final note, both through discussion with MWH and my own feelings, it is felt that this questionnaire was successful and that a larger pilot questionnaire could yield even more interesting results. This concept is explored in the future work section in Chapter 8.

## **6.0 Sustainable Materials Selection Tool**

### **6.1 Introduction**

This stage of the research was conducted concurrently with the work described in the previous chapter. As the circumstance regarding Trident West's situation with suppliers was explored it had been agreed to design a tool that designers and engineers within Trident West could use to make informed decisions regarding their choice of construction materials. This chapter explains the process by which the M<sup>2</sup> (Materials Matrix) was designed and developed, based on the ideas that MWH had begun to develop prior to this research. It addresses its use as a prototype tool and specifically how it could be used in the Trident West design process to make their projects more sustainable through appropriate material choice.

### **6.2 Sustainable Materials**

The careful extraction and use of natural resources - the basis for all construction materials - is necessary for the continued success of the construction industry (BSRIA, 1999). Nowadays designers who select the necessary materials for construction projects are faced with a vast range of materials capable of doing the job by meeting technical specifications and cost considerations. Many of these materials are for one reason or another unsustainable when considering their use in a construction project, whether they are tropical hardwoods from Brazilian rainforests, where biodiversity is a major issue, or stone transported all the way from Australia, many of them invoke unnecessary social or environmental impacts that could be avoided through enlightened materials choice.

The question that remains is "What constitutes a sustainable material". Using the three circles of sustainability model from Chapter 1 (McClaren, 1998) it is possible to explore the economic, social, and environmental issues associated with a material and therefore arrive at a definition of what a sustainable material really is. The economic issues, such as cost factors related to materials for construction, are relatively easy to understand. The cost of material is the simplest representation of this: the scarcer the resource or the further the distance that it has travelled, the less economically sustainable a material is. The environmental sustainability of a material is a measure of the environmental impacts that the material has caused, throughout its lifecycle, whether they are visible, e.g. scarring of the landscape resulting from materials extraction, or the less visible effects such as biodiversity loss through extraction or CO<sub>2</sub> (Carbon Dioxide) emissions causing global warming. The environmental impacts, as the guides in Chapter 4 highlight, are quite well known and numerous, e.g. acid rain, deforestation, ozone depletion and global warming to name a few. Lastly, the social sustainability issues arising from materials choice are definitely the least tangible of all impacts. Many social impacts arise from environmental impacts and good examples include global warming which will lead to increased skin cancer cases, and noise and odour issues, which may arise and subsequently reduce people's quality of life. A material that can be considered truly sustainable is one that satisfies economic, environmental and social sustainability criteria.

Fuad-Luke in his Eco-Design handbook (2002) looks at materials in the context of where they have come from. He describes materials as either coming from the biosphere and lithosphere or from the technosphere.

Materials from the biosphere are those that are derived naturally from the living components of the planet and are renewable in their nature, and come from plants, animals or micro-organisms. Biosphere materials when disposed of accordingly at the end of their life are freely returned to the natural cycles from which they originate. Biosphere materials are the most inherently sustainable materials by their nature. Comparatively, lithosphere materials are those materials that come from the Earth's crust. They fall into two distinct categories, those that are plentiful in supply all over the Earth, such as sand and clay, and those that are more limited both in supply and geographic distribution; these include fossil fuels, such as coal, and metal ores. Some of these materials take a long time to regenerate in the lithosphere, e.g. coal, oil and gas so they are not sustainable in the short term but through careful management and no overuse they will always replenish themselves eventually. Lastly there are those materials from the technosphere. These materials are derived from either the biosphere or the lithosphere and are processed by industrial processes to produce non-renewable, unsustainable materials, e.g. oil (a lithosphere fossil fuel) is processed to make plastics. These technosphere materials are not suitable for returning to the natural flows of materials and are not biodegradable, as they have been transformed from their natural state. These materials must be reused in a world where resources are limited and recycling them is often the key to doing this. However, this is not without a cascade of problems because often the purity of the material is not as good as when first produced and they may not meet future technical specifications. These terms are beneficial when trying to understand material flows and have been utilised in the Materials Matrix discussed next.

### **6.3 Materials Matrix (M<sup>2</sup>) Design Process**

Prior to this research project MWH were already considering the use of some form of matrix that would look at the lifecycle impacts of a particular project element, e.g. pipelines in social, economic and environmental terms. The idea although initially sound was found to be an extremely vast and complex subject akin to a full lifecycle analysis for a single project element. From these initial findings and dialogue between myself and MWH it was determined that this approach would require many man hours of work. The results of these conclusions were that efforts should be directed more toward the materials actually to be used in construction instead. The basic reasoning surrounding this was that if the materials used in construction were investigated on the grounds of their potential sustainability then any resulting construction project would benefit greatly by reducing its impacts through enlightened materials choice. In conclusion it was decided by MWH that materials choice has the biggest potential to reduce the social and environmental impacts of a TWA site or installation throughout its life without actually having to complete a full lifecycle analysis.

The Materials Matrix or M<sup>2</sup> was the idea of the author to meet the needs of MWH and their desire for a tool which designers and Engineers within the Trident West Agreement could use.

The Materials Matrix would have to provide a comprehensive sustainability assessment strategy with regard to materials. The definition provided in 6.2 stipulates that economic, environmental and social factors must be considered if materials are to be judged as to how sustainable they are. It was decided that any assessment procedure for materials within the matrix must entail all three of these dimensions of sustainability. In addition to this the definitions of biosphere, lithosphere and technosphere materials

by Fuad-Luke (2002) would be used when actually classifying materials themselves, for example: wood is a biosphere material; slate a lithosphere material; and Polyethylene a technosphere material.

The three environmental methods for selecting materials from Chapter 4 were consulted for assessment criteria in addition to input from MWH and Trident West staff and the results from Chapter 5. The assessment criteria are listed below in 6.4 with brief descriptions of each one and why they are there.

The structure of the matrix itself was designed to emulate lifecycle thinking. This is a process by which no complex calculations and data sets are required, as in a lifecycle analysis, but more a method of considering the same stages; extraction, production, distribution, use and disposal of a material (Anink et al, 1996). The matrix material assessment criteria were arranged in a way so that those to do with the entire lifecycle, in this case embodied energy, were considered first and looked to then follow the structure of 'lifecycle thinking', from the distance from the source of the materials to the construction site (or geographical region) right through to the intended life-span of the material.

From the outset of the work to design and develop this tool it was realised by myself and MWH that the context that materials are placed in would largely effect the potential impacts that materials could have on different assessment criteria, for example steel used in a window frame might well entail more embodied energy than the steel used in structural reinforcements.

The decision to design this tool in this fashion was focused the entire time around the need to develop a tool that designers and engineers would readily use and accept.

There was some debate as to whether numerical data would be best or whether the

information could be displayed more visually. The time-scale for this research did not allow investigation into which method would see the most effective use of the Materials Matrix tool but certainly opens up a possibility of future research into this area. Regardless of this the Materials Matrix was designed and developed as a tool for selecting materials on the basis of how sustainable they are. It may be used singularly to choose between materials on one assessment criteria, for example choosing between concrete, steel and plastic pipeline materials on the basis of the one with the lowest cost or highest recycled content. Similarly the designer or engineer can use multiple criteria to select a material and get a feel for how sustainable a material is generally. This would have practical applications regarding the original situation where one of the senior design engineers within Trident West stated that sometimes two materials may cost the same and have the same technical specification as one another but it would normally be up to them to choose subjectively which one they considered more suitable. With the aid of the Materials Matrix using multiple criteria, based on the literature reviewed, the design engineer would be able to make a more informed choice over which material to choose on the basis of how sustainable it is. This would see the subsequent result of them picking a more sustainable solution for the Trident West Agreement and subsequently make their construction activities more sustainable.

#### **6.4 Material Matrix (M<sup>2</sup>) and Description**

A copy of the matrix as it was originally intended to look is included in Appendix C. An extensive but not definitive list of materials is attached to it showing the enormous potential scope for application (and the number of different materials that Trident West uses) and also several additional assessment criteria that were not included in the final

matrix shown overleaf. A description of each of the assessment criteria follows and includes the sources of information for those criteria that data were found for, in addition to any difficulties arising from finding data to put in the matrix.

The criteria were selected through a process of examining the potential barriers to sustainability highlighted in the BSRIA report in the literature review in Chapter 2 in addition to those factors highlighted by CIRIA as important factors regarding the construction industry and sustainability. It also uses prior knowledge by members of MWH and the author in addition to the material selection guides in Chapter 4 to supplement the areas highlighted in the literature review to produce as comprehensive amount of information to make the process possible.

The Materials matrix was filled in using a list of six different materials that were agreed upon within MWH following discussions about which materials were used on a regular basis and those which were used in the manufacture of pipelines. They were as follows:

- i) Timber (Wood)
- ii) Steel
- iii) Concrete (Pipelines)
- iv) Aluminium
- v) Clay Bricks
- vi) Plastic (Polyethylene Pipelines)

6.4 Materials Matrix (M<sup>2</sup>)

| Sustainability Impacts              | £ | Embodied Energy | Durability (intended lifespan of materials) | Recycling Factors |                        |                        | Waste Potential | Water Consumption | Biodiversity | Ozone Depletion |
|-------------------------------------|---|-----------------|---------------------------------------------|-------------------|------------------------|------------------------|-----------------|-------------------|--------------|-----------------|
| Materials                           |   |                 |                                             | (a) % contained   | (b) % capable of being | (c) energy required to |                 |                   |              |                 |
|                                     |   | Mj/Kg           |                                             |                   |                        |                        |                 |                   |              |                 |
| Biosphere and Lithosphere Materials |   |                 |                                             |                   |                        |                        |                 |                   |              |                 |
| Timber                              |   | 0.6             | 60 yrs                                      | 0                 | 100                    | Low                    | Low             |                   |              | Low             |
|                                     |   |                 |                                             |                   |                        |                        |                 |                   |              |                 |
| Technosphere Materials              |   |                 |                                             |                   |                        |                        |                 |                   |              |                 |
| Aluminium                           |   | 235-335         | 20 yrs                                      | High              | High                   | Low                    | High            |                   |              | High            |
| Steel (Virgin)                      |   | 32              |                                             |                   | Medium                 |                        |                 |                   |              |                 |
| Concrete (Pipelines)                |   | 0.7-1.0         | 100-120 yrs                                 | 20                | 60                     | Low                    | Medium          | Yes               |              | Low             |
| Plastic (Polyethylene Pipelines)    |   | 85-100          | 50-100 yrs                                  | Medium            | High                   | Low                    | Low             | Yes               |              | Low             |
| Clay Bricks                         |   | 2.0-10.0        | 60 yrs                                      | 0                 | 100                    | Low                    | Medium          |                   |              | Low             |

| Sustainability Impacts              | Noise & Odour Pollution | Distance to Source | Repairability | Reusability |
|-------------------------------------|-------------------------|--------------------|---------------|-------------|
| Materials                           |                         |                    |               |             |
|                                     |                         |                    |               |             |
| Biosphere and Lithosphere Materials |                         |                    |               |             |
| Timber                              |                         |                    |               |             |
|                                     |                         |                    |               |             |
| Technosphere Materials              |                         |                    |               |             |
| Aluminium                           |                         |                    |               |             |
| Steel (Virgin)                      | Medium                  |                    | Possible      | Medium      |
| Concrete (Pipelines)                | Low                     | UK                 | Replace       |             |
| Plastic (Polyethylene Pipelines)    |                         |                    |               |             |
| Clay Bricks                         |                         |                    |               | High        |

### **6.4.1 Cost**

This criteria represents the traditional economic element of sustainability. Cost is still a major deciding factor in the choice of materials in any industry and Trident West is no different. The data required to fill in this section of the matrix is purely dependent on market prices of different materials at the time and as such is a variable. The designer or engineer prior to materials selection should fill in this section of the matrix.

### **6.4.2 Embodied Energy**

This criteria considers the energy used to extract, process, transport and assemble a material into its desired form. Fuad-Luke (2002) defines embodied energy as a measure of eco-efficiency, whereby it is the degree of efficiency of the use of energy within an ecosystem. Any material used in a construction project represents stored energy, whether it is from sunlight or from the lithosphere. This amount of energy varies greatly dependent on the amount of energy used in processes like extraction and the further processing of materials.

Figures for embodied energy are readily available and the most recent figures the author could find are included from Fuad-Luke (2002) and are measured in Megajoules per Kilogram of material (Mj/Kg).

The values shown in the Materials Matrix range from very low embodied energy values for wood, 0.6 Mj/Kg which is a natural biosphere material through to very high values, 235-335 Mj/Kg, for aluminium which involves huge amounts of energy to transform it from bauxite (Aluminium ore) into aluminium.

As a rule any material which offers a lower embodied energy value should be preferable due to its greatly reduced environmental impacts. However, some lower embodied energy materials have a shorter life-span than their high embodied energy material counterparts. This refers to some form of energy payback period over the

life of a structure (Treloar et al, 2001). High embodied energy values in the materials used to construct a building that lasts 2 years are very unsustainable. However, if the same materials and associated energy values were used to construct a building that lasted 100 years this would be seen as more sustainable.

I suggest from this that MWH and the Trident West Agreement should consider the embodied energy values of the materials used in construction over the life span of the building or site to ensure the most sustainable choice of materials possible for the required job.

#### **6.4.3 Durability (Lifespan)**

This criteria refers to the intended lifespan of the material or its supposed longevity. The longer the material lasts the more sustainable the material can be said to be and even a relatively high amount of embodied energy in a material can be justified to some extent if the material lasts a long time. This is one area of the matrix where the data is relatively context specific, the figures for concrete and plastic within the Materials Matrix arose through the questionnaires to suppliers and manufacturers of pipelines to the Trident West Agreement so the data here is highly relevant to MWH and their activities. The data for the remaining three materials all came from the BRE Green Guide to Specification reviewed in Chapter 4. The information here is used from profile sheets and again relates to specific contexts, for example the figure for aluminium of 20 years, came from a profile sheet for window frames. The figures for steel were unavailable in any of the resources researched and to date the manufacturer of steel pipes for Trident West Agreement has not yet returned the requested questionnaire results.

#### **6.4.4 Recycling Factors**

The following three factors all looked at some aspect of a material's recyclability from its production through to its potential to be recycled at the end of its useful life.

##### **6.4.4.1 % Recycled Material Contained**

The percentage contained category looks at the amount of recycled material that is contained in the materials that Trident West purchase. Materials from the technosphere will benefit particularly from having a high recycled content as they are less readily returned to natural cycles and need to be recycled to recover the material after it has been used. Both wood and clay bricks contain little or no recycled content, hardly surprising when you consider that wood is grown naturally and bricks are more readily reused than recycled (See 6.4.12). It can also be seen that both aluminium and polyethylene, technosphere materials, have relatively high-recycled contents with concrete pipelines also consisting of nearly a quarter of recycled aggregates material.

The potential for materials to contain recycled content adds greatly to their sustainability through inclusion of what would probably have been discarded and unbiodegradable (in the case of technosphere materials) waste.

The data for this particular criteria was drawn from a variety of sources including the Sustainable Building Handbook and The Green Guide to Specification, both reviewed in Chapter 4, and also from the supplier and manufacturer questionnaire data in Chapter 5. Figures for the recycled material content of steel were not available to complete this part of the matrix.

##### **6.4.4.2 % Capable of Being Recycled**

This criteria examines the potential for a material to be recycled at the end of its functional life. The information required to fill in this area of the Materials Matrix

came predominantly from the Sustainable Building Handbook but was supplemented with information from the supplier and manufacturer questionnaires with regards to the polyethylene pipelines.

It can be summarised from the data that recycling is reasonably prevalent in the UK today and that all of the materials displayed in the matrix show a medium to high percentage possibility of being recycled again, contributing to their overall sustainability.

#### **6.4.4.3 Energy Required to Recycle**

The last of the recycling factors within the Materials Matrix looks at the amount of energy required to actually recycle a material graded on a low, medium or high basis. The basic rule is that if a material takes a high amount of energy to recycle then it is adding to its embodied energy values thus making it less sustainable.

The data for this section of the M<sup>2</sup> was utilised from the Sustainable Building Handbook, supplier and manufacturer questionnaires in addition to the Green Guide to Specification.

Figures for all the materials except for steel were found to be low, ranging from the little effort it takes to crush and grade concrete through to the vastly reduced amounts of energy it takes to recycle aluminium compared to its extraction.

#### **6.4.5 Waste Potential**

This assessment criteria looks at the amount of waste potential concerning the materials extraction, manufacturing, construction, use and end of life. The data for this section came from the Green Guide to Specification and the supplier and manufacturer questionnaires from Chapter 5. The amount of materials and natural resources contained on Earth are finite and as such measures should be taken, to reduce as much as possible, the amount of waste produced. Again no figures for

steel have been found available yet the remaining results contrast starkly: Aluminium has a very high waste potential, this is mostly due to its wasteful extraction processes; conversely both timber and plastic pipelines have relatively low values, the former due to all parts of a tree being used in some way and the latter due to efficient manufacturing processes where all waste can be melted down and reused. An example of this can be found in Appendix A.

It can be summarised that materials, which involve a high amount of waste potential, should be avoided and those, which take more care not to waste so much material, should be ascribed to.

#### **6.4.6 Water Consumption**

Water is one of the most valuable resources on Earth. Without it life could not survive. The issue of water conservation is one that should not be taken lightly and through the lifecycle of a material all water use should be minimised and measured. This criteria uses a simple yes or no measurement of whether these factors are taken into consideration. The context of the materials production is also important. Limited data was only available for this field, and most of it was sourced from the questionnaire results from Chapter 5. The information refers to plastic and concrete pipelines that are used by Trident West where both respondents clearly stated that the amount of water they use is carefully metered at all times.

It can be suggested that with regard to specific suppliers they should all adhere to such water management strategies. Those that do not should be encouraged to do so or risk not being picked as a supplier to the Trident West Agreement.

#### **6.4.7 Biodiversity**

This criteria looks at the variety of life in all its forms. From a genetic, species and ecosystem level the diversity of life itself is considered. This is one of the areas where data is not available and at current the biodiversity issues associated with the lifecycle of a material from its extraction to eventual decommissioning are not measured.

The Materials Matrix was designed to include some form of measure concerning biodiversity but I have to suggest that it should be excluded until suitable measures for biodiversity exist and that MWH will for the time being be unable to measure biodiversity impacts with respect to the materials their suppliers use.

#### **6.4.8 Ozone Depletion**

The more damage that is sustained from CFC gases (Chlorofluorocarbons), the more UV (Ultra-Violet) light passes through the Earth's atmosphere and brings with it increased health risks such as skin cancer and contributes to global warming. The lower the amount of CFC's or other ozone depleting gases that are emitted through material extraction and manufacturing processes then the less risk is posed to society and the environment.

The information and data regarding this issue is ranked on a low, medium high basis and the information has come directly from suppliers of concrete and plastic pipelines with the remainder coming from the Green Guide to Specification.

The research highlights that aluminium has an extremely detrimental effect on ozone levels and should be avoided if ozone depletion is a primary concern for MWH and the Trident West Agreement. The rest of the materials, with the exception of steel, which has no data available, all have low levels of ozone depletion.

When making materials choices designers and engineers should avoid those with a high ozone depletion value unless necessary and should move toward more

sustainable materials that do not have such potentially large social and environmental impacts.

#### **6.4.9 Noise and Odour Pollution**

Noise and odour pollution is a criteria that MWH were particularly keen to include in the Materials Matrix as it is an important issue when carrying out Environmental Impact Assessments (EIA's) on any potential projects. This is a manufacturing issue and as such is relatively context specific. The only available data for this criteria comes from the questionnaires relating to concrete and plastic pipes manufacture which both rank as low. Further information was found from the Sustainable Building Handbook which summarise that steel manufacturing and processing suffers from medium levels of noise and odour pollution.

In summary, designers and engineers should look to choose those materials which have the lowest noise and odour pollution and subsequently reduce the social impacts of any such activities making the materials used more sustainable.

#### **6.4.10 Distance to Source**

The proximity of materials from their area of origin to their site of intended use is an important issue. There is little point using timber from sustainable sources, like those certified by the FSC (Forest Stewardship Council) if it is only to be transported by lorry hundreds of miles. The benefit of the use of sustainable wood is negated by the impacts associated with its transport.

A scale of Local, UK, Europe, and Worldwide is used in the Materials Matrix and any designers or engineers looking to choose construction materials should look at their locality as being a major factor. Local materials not only reduce the environmental impacts associated with transport but also increase social benefits to an area where a project is happening by utilising local materials and therefore local labour sources.

The designer or engineer should fill out the Matrix at the time, as the location of the project itself is dependent on the answer given. However one of the responses to the questionnaire by one of the Trident West suppliers established that all concrete used in pipelines by Trident West was sourced from the UK. This can be perceived as reducing environmental impacts and increasing the social dimension of sustainability by providing jobs in the UK in addition to the economic benefits of keeping the process within the UK.

It is therefore of great importance to try to obtain all materials as locally as possible in relation to the construction site. If this is achieved it would greatly contribute to the overall sustainability of the Trident West Agreement and the construction projects they achieve.

#### **6.4.11 Repairability**

The repairability of a material is a measure of the likelihood that a material will be repaired if damaged in any way. This is once more a context specific issue and the situation the material is used in needs to be assessed to determine an answer. The Material Matrix looks at data supplied by both concrete and plastic pipeline suppliers and manufacturers and it can be seen that concrete is not repairable due to industry standards. However polyethylene pipes do indeed have the potential to be repaired if requested by the owner of the pipelines.

It is apparent that the repair of a pipe should be endeavoured before replacing the entire section and that it may be considered more sustainable to repair rather than replace.

#### **6.4.12 Reusability**

This final assessment criteria looks at the likelihood of the material to be re-used at the end of its life. The Sustainable Building Handbook was the source of information

here and using a rating of low, medium and high once more it can be seen that both steel and clay bricks have a good chance of being re-used.

Re-using a material is preferable to recycling it when looking at the UK waste management strategy as outlined by the government (Woolley QC et al, 2000). It uses none of the energy required in recycling and just uses the material as it is at the end of its current functional life for some other purpose. Steel reinforcements in buildings are often used again elsewhere and clay bricks are used in the foundations of buildings.

It can therefore be concluded that it is preferable to re-use rather than recycle, as it is more sustainable through less energy usage.

Reuse is also inherently a behavioural issue, it is a result of people's over-eagerness to throw something away after its use and purchase something new again rather than reusing the resources that exist already. This is a strategy that not only saves resource use but also financial gain can be achieved if old materials are reused again instead of new ones.

## **6.5 Conclusions**

I feel that even though it has not been tested the Materials Matrix shows great potential as a prototype tool for designers and engineers at Trident West. This has been agreed within MWH and if issues arising from the lack of data to fill it in completely are rectified they agree it has a real chance of being used in construction projects. It could even see wider application to all of MWH's construction projects. The tool allows designers and engineers to make informed decisions regarding the choice of materials whether by a single criteria such as cost or through a combination of factors such as recycled content, water consumption and ozone depletion to choose a comprehensively more sustainable material. We can therefore initially conclude that the Materials Matrix shows a great deal of potential

functionality. With future work involving designers and engineers to refine and modify the tool, and also increase their ownership through their contribution to the design process, it would produce a more useful, detailed tool that people within Trident West would actually use to choose more sustainable materials.

One of the initial problems with the Materials Matrix concerns the lack of data to complete it. I feel that there are two primary reasons for this. Firstly there is a lack of data concerning the environmental and social impacts of materials in general; the data collected is often five to ten years old. Secondly much of the information used from the guides reviewed in Chapter 4 is very context specific. For example the data concerning aluminium in the matrix although informative, is actually inaccurate, as it is referring only to aluminium used in window frames. Whilst the matrix clearly provides approximate figures they are by no means a reliable source. This does however draw attention to the fact that during this research a context was not originally specified for the selected materials and information supplied is relatively general in nature.

One other notable conclusion included the presentation of the data within the Materials Matrix itself. The use of figures and grading is predominant yet it was undecided within MWH as to whether a simple use of different sized dots such as that used by Woolley in his Green Building Handbook (1997) which provide instant inspiration and information for designers to make quick choices would be preferable. Alternatively it was noted that engineers prefer the use of numbers and details with which to make informed decisions. Although an interesting concept the time constraints on the project did not allow these eventualities to be explored but certainly earmarks them for future interest.

The results from this section can be summarised by concluding that the Materials Matrix certainly shows potential as a prototype tool for engineers and designers and has highlighted many areas of interest.

The following chapter looks to discuss all three research chapters, the environmental methods of materials selection, the supplier and manufacturer questionnaires. It also discusses some of the key themes that have evolved in relation to one another and draws out any key findings.

## **7.0 Discussion**

### **7.1 Introduction**

This chapter collates the major discussion points from Chapters 4, 5 and 6 and brings them together with regards to the research question in Chapter 1. This thesis has looked at a range of factors and issues in the research affecting the sustainability of materials and several key themes have been drawn out and are described as follows:

### **7.2 The Importance of Choosing More Sustainable Materials for Construction**

From the initial literature review it has been highlighted that the construction industry is in need of major reform with regard to its activities and efforts need to be made to make it more sustainable. The materials used in construction play a major role in the cumulative impacts of the construction industry and have the potential to influence economic, social and environmental aspects of sustainability.

These views are confirmed within Chapter 4 where the current environmental methods of selecting materials all recognise that materials choice at the design stage of a project is an excellent way to reduce potential future environmental and social impacts. These guides although only looking predominantly at the environmental impacts of construction materials offer a starting platform for a more sustainable materials selection method that could be used within the construction industry.

Similarly the designers and engineers within MWH realise that they have the potential to reduce environmental and social impacts through informed materials choice. They provided the inspiration for the development of the Materials Matrix in Chapter 6 and the research results will hopefully provide them with an insight into

both what makes a material more sustainable in addition to being able to examine the structure of the Materials Matrix itself.

The suppliers and manufacturers to the Trident West Agreement that were questioned in Chapter 5 were also generally interested in the concept of sustainable materials even if they did not currently operate in accordance with such principles. This indicates that there may be some underlying interest in the area, which I feel, could benefit from more dialogue between Trident West and its suppliers to cultivate the notion of more sustainable materials use in construction.

Within Trident West it would seem that there is not only a case for using more sustainable materials in construction but that there is genuine interest in this area. These findings resulted in the Materials Matrix in Chapter 6. It is hoped that this tool may capture designers and engineers attention within Trident West and that through its use the construction projects that MWH and Trident West engage in can become more sustainable through materials choice.

### **7.3 The Supply of Sustainable Materials**

The idea of more sustainable materials discussed above may well be the key to success in making construction projects more sustainable. However, without a supply of these necessary materials from manufacturers and suppliers this cannot occur. Some suppliers and manufacturers interviewed in Chapter 5 comment that even though they are interested in sustainability and sustainable materials they are not actively moving toward sustainability. The summary in Chapter 5 highlights that work in partnership between suppliers and manufacturers and the Trident West Agreement is necessary. This is an idea that is replicated in the literature review in 2.5 in the section that looks at the CIRIA report on the construction industry and sustainability that identifies working in partnership with suppliers and clients to form long term relationships with clients and suppliers (CIRIA, 2001). MWH already do

this with their clients at Trident West and the opportunity to do the same with suppliers is an option. There are two main strategies that arise from the findings in Chapter 5. The first looks at the increased education of suppliers and manufacturers by Trident West with regards to the supply of sustainable materials. If suppliers are not aware of such concepts they may have no idea of the importance of the issue and will never look at the supply of sustainable construction materials themselves. Secondly Trident West needs to make more demands on their suppliers and stipulate that they prefer to procure materials of a sustainable nature. I envisage that this would force suppliers and manufacturers to endeavour to conduct more sustainable business practices resulting in both increased number of sustainable materials being produced and stimulating the supply chain to respond to this request and companies gaining competitive advantage through meeting this request.

Although the guides in Chapter 4 do not emphasise these points I feel that more guidelines of this nature would be produced if suppliers and manufacturers increased their standards with regards to the concept of sustainability, this would result in more tools available to select materials on the basis of how sustainable they are and allow organisations like Trident West to make their construction projects more sustainable through materials choice.

#### **7.4 Lifecycle Thinking**

One of the more general themes relating to the research area was the use of lifecycle thinking in the construction industry. The literature reviewed in Chapter 2 (See Figure 5) looks at the lifecycle of a sustainable construction project and how it can deliver more sustainable assets from lifetime costing through sustainable design to produce improved construction processes. It then looks at sustainable flexible assets in addition to the optimal use of existing assets and eventual site remediation before the process begins again (CIRIA, 2001). These ideas are similar to those

found in the Green Building Handbook and the Sustainable Building Handbook (both reviewed in Chapter 4) that consider construction materials throughout their lifecycles. These include “the extraction of raw materials through to processing the material at the end of its life” (Anink et al 1996) and this idea has been a major factor in the development of the Materials Matrix and the assessment criteria used within it. Issues such as embodied energy look at the energy costs involved with a material throughout its life whilst other criteria look at specific areas of a materials lifecycle, e.g. re-usability of material at the end of its functional life.

It was noted that suppliers and manufacturers made no mention of lifecycle approaches to their products and processes. This may have been due to either not asking the right questions to yield this sort of information or again a lack of knowledge on their part.

I can safely say that the numerous literature concerning lifecycle thinking and the wealth of information regarding technical lifecycle assessments available in the public domain clearly indicates that this is an issue that MWH and Trident West really must consider in the future in relation to the materials they use and procure in addition to the processes they use in construction.

## **7.5 Lack of Data Concerning Sustainability of Materials**

From the range of literature reviewed at the start of this thesis it is noted that although the sustainability of materials is an important agenda both within the construction industry and other industries the research conducted shows a lack of specific data relating to the sustainable impacts of materials. Specific papers are available regarding various aspects of sustainability of materials but there is a general lack of direction in this field. Both the questionnaire results from suppliers and manufacturers and the lack of data to complete the Materials Matrix highlight that the lack of information regarding the sustainability of materials is going to be a

future issue. The issue of generating this data relies on both the top down support of companies from senior management positions as well as bottom up enthusiasm shown by designers and users of materials. Through this co-ordination of efforts increasing pressure may be placed on suppliers and manufacturers and subsequently move up the supply chain to those who extract materials and natural resources. Only when this process has occurred do I feel that through increased responsibility and accountability of suppliers, manufacturers, and extractors of materials for use in the construction industry will more data become available to complete those areas within the Materials Matrix that remain unfilled. Once complete the matrix will provide MWH and the Trident West with a necessary tool that will allow them to make their construction projects more sustainable through their informed choice of materials.

## **7.6 Weightings and Rankings of Different Assessment Criteria used in the Materials Matrix**

The issue of trying to rate and compare different assessment criteria in materials selection tools is one that has arisen throughout the duration of this research. The materials selection guides in Chapter 4 provide conflicting views on this subject. The Green Guide to Specification insists that different criteria can be given different ratings as shown in Figure 8 where they rank CO<sub>2</sub> as the most important issue by far (BRE, 1998). Conversely Woolley in his Green Building Handbook is quoted as saying "The balancing of different factors is a political rather than scientific matter" (Woolley et al. 1997). This could lead to some indecision as to which approach to adopt but consultation within MWH revealed that by trying to consider the issues of weighting or ranking different criteria the problems are two-fold. Firstly the issue of sustainability is already multidimensional in its nature, as such it is perceived by both those within MWH and myself that weightings and rankings would over complicate the issue of sustainable construction materials. Secondly whoever was to decide on

the appropriate rankings would be largely influenced by their own subjective views, as a result what someone believes to be the most important criteria could be perceived by someone else as completely wrong.

These findings are interpreted by the absence of any form of weighting or ranking in the Materials Matrix and I recommend that these findings be adhered to if any further developments are made to the Materials Matrix by MWH in the future.

## **7.7 Contextual Considerations Regarding Materials**

This final point in the discussion chapter concerns the contextual considerations of materials. Although not something immediately apparent in the literature reviewed it became obvious from the remainder of the research that this was an issue that was prevalent. The information gained from the environmental methods of selecting materials clearly highlights that the guides only supply data regarding materials in specific context, e.g. plastic coated steel in external wall construction, (BRE, 1998). This issue again occurs in Chapter 5 of the thesis with first a comment by the Head of Sustainable Development Europe, at MWH, during discussions about sustainable materials which stipulated that the context materials are used in greatly affects their individual sustainability impacts. The respondents to the questionnaires were only able to provide accurate data used to fill in the Materials Matrix because the information requested from them related specifically to the pipeline materials they supply Trident West with.

This notion is further compounded by the fact that the Materials Matrix was filled in partially using data that was taken out of context, and that the figures for wood, aluminium, clay bricks and steel are all approximate and not accurate. However the data that revolves around both plastic and concrete looks specifically at pipelines used by Trident West and is great value to both MWH and Trident West.

Any future enquiries about materials that the Trident West Agreement uses should take contextual considerations into account and try to use data gleaned from their own suppliers and manufacturers as it is the most valuable and accurate to them. I feel that by doing this Trident West could really start to see the use of more sustainable materials in their construction projects and thus increase their sustainability whilst simultaneously pushing for suppliers and manufacturers to also become more sustainable and provide more data concerning the exact materials Trident West uses.

## **8.0 Conclusions and Future Work**

### **8.1 Introduction**

This chapter looks at the major conclusions of this research in a summary of the work and its achievements and looks to answer the research question posed in Chapter 1. This chapter finishes by looking at any potential areas of interest or research that have arisen through the course of this research in the future work section.

### **8.2 Conclusions**

The conclusions of the thesis look to satisfy the original aims and objectives set out in Chapter 1.

The original aim of the project was to provide information regarding the sustainability of materials used in the construction industry and to develop a materials selection tool that will enable designers and engineers to choose materials for construction projects. It is hoped that this will increase the overall sustainability of the projects that MWH and Trident West are involved with.

The research question formulated in Chapter 1 was used to address this aim and was as follows:

*'Can MWH, in the projects they tackle within the Trident West Agreement, make their projects and activities more sustainable particularly through their choice of construction materials?'*

I believe that the research question was a useful tool in answering the project aims and objectives. Through the research methods and results collected in this thesis, in addition to working in close collaboration with MWH, I feel able to answer the

research question by stating that MWH can make their projects more sustainable through their choice of materials.

A review of the current literature that exists on sustainability and its wider implications for design, construction and materials have all been explored. It stresses the gap in knowledge that this research has sought to bridge and also that sustainability in the construction industry is a very important concept that considers economic, environmental and social factors in a multidisciplinary fashion.

A draft questionnaire was carried out on suppliers and manufacturers of the Trident West Agreement that initiated a series of interesting responses. This enabled discussion about the role suppliers play in the provision of sustainable materials, as well as generating data that was utilised in the Materials Matrix in Chapter 6.

The opportunity to work within Trident West has given me a good insight into their design practices through informal conversations and interviews with members of staff I have understood the concept of Asset Management Plans (AMP's) and how they affect the potential procurement of construction materials. Conversations with designers and engineers highlighted a need for more information regarding construction materials whilst senior engineers have indicated those project elements that would be a good example in terms of sustainable construction materials (See Appendix B).

The research has also included the development of a prototype tool, the Materials Matrix ( $M^2$ ), which was designed and developed using initial ideas generated by MWH prior to this project. The Matrix was designed as a tool to be used by designers and engineers within the Trident West Agreement to help inform their decisions at the design stage of projects with regard to the materials they choose for construction. This particular aim was very important to the overall research question and through its development I assume that the tool does indeed have the potential to make construction projects more sustainable by providing more information

regarding sustainable impacts of materials. It was discussed in MWH that the Materials Matrix does have a future as a materials selection tool. However, one of the major research findings was that the data available and the context that materials are used in are very important when considering the sustainability of materials. Should these issues be rectified I predict that the tool could be more generically applied across all of MWH's construction activities.

In the discussion chapter, I have drawn out some of the key issues and themes that were prevalent throughout the research. These are as follows:

- i) The importance of choosing more sustainable materials for construction
- ii) The supply of sustainable materials
- iii) Lifecycle thinking
- iv) Lack of data concerning sustainability of materials
- v) Weightings and rankings of different assessment criteria used in the materials matrix
- vi) Contextual considerations regarding materials

In addition to this any issues that are seen as potential barriers to sustainability and the use of sustainable construction materials have been flagged throughout the thesis.

In overall conclusion I feel that I have answered the research question sufficiently and in doing so have satisfied all of the aims and objectives set out in the introductory chapter in addition to generating the requested deliverables for MWH. This project is a small part of a much larger project MWH are involved in regarding the Trident West Agreement and how to make their operations more sustainable in general over a two year period. This in turn is related to MWH's ongoing commitment to 'Strive to become a global leader in the delivery of projects and

solutions that improve the quality of life, and the business efficiency of their clients' (MWH, 2002).

### **8.3 Future Work**

Throughout the duration of this research I have uncovered or opened the way forward for future research in the area of sustainable construction materials. This final section of the thesis highlights these areas.

The research questionnaire that was conducted on a small sample of four suppliers and manufacturers to Trident West produced some interesting results both regarding the corporate level of sustainability within suppliers and manufacturers as well as more specific materials issues. The questionnaire itself also caused considerable interest from a number of these respondents about the issues of sustainability and the data provided from this questionnaire was extremely valuable in filling in the Materials Matrix with information specific to materials used in the pipelines by Trident West. I propose that this questionnaire should be conducted on a larger scale, possibly extending to all suppliers and manufacturers within the framework agreement. The data generated from this extended questionnaire would be invaluable to MWH and the Trident West Agreement and would allow the Materials Matrix to be filled in for many project elements including tanks and chambers and the various materials these project elements require for construction. The potential then for making projects more sustainable through materials choice takes on a new dimension when the magnitude of this idea and the potential data it could supply are considered.

In addition to the idea of expanding the questionnaire sample I have realised the potential of the questionnaire as a tool for improving the sustainability performance of suppliers and manufacturers to the Trident West Agreement. I suggest that not only are existing suppliers and manufacturers questioned on their sustainability

performance but that any potential companies that wish to supply materials to or manufacture materials for the Trident West Agreement should be screened using this questionnaire to assess their potential sustainability impacts of their operations and materials they supply.

In this way the questionnaire would drive suppliers of materials to utilise more sustainable business practices and subsequently supply more sustainable materials as they endeavour to meet the challenge of these questions.

The opportunity for MWH and Trident West to work in partnership and cultivate excellent relationships would be seen as not only an increase in the social sustainability of the relationship but that the overall sustainability performance of the construction industry improves and moves away from its current poor image with regard to unsustainable resource and energy consumption.

The final two areas highlighted for future research both look at the Material Matrix in Chapter 6. Firstly the development of an abridged form of the matrix that considers those issues that MWH and the Trident West Agreement agree to be the most important. This idea would see the most important issues receiving the most attention without using the idea of weightings or rankings that has been discussed as a complicated and subjective issue in Chapter 7. The tool would still aid designers and engineers in their materials choice and therefore the original aims of this research would still be achieved. It would, however, be simpler to both fill in with data and use without so many criteria.

The final idea looks at the presentation of the data within the matrix. There was some debate amongst MWH employees and myself as to the best possible presentation of data within the matrix. Some of the designers at Trident West had commented that a series of dots denoting the level of impacts of any particular criteria (See Figure 11, Chapter 4) would be most useful to provide instant inspiration about which materials should be used. Conversely though some of the

engineers within MWH stated a preference for numbers and figures which they could scrutinise when deciding between which construction materials to use. This I feel is something of a culture issue within MWH and would certainly provide an interesting focus for some future work to be carried out in the area.

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# Appendices

## Appendix A

### Supplier Questionnaire Answers

The following scripts are an exact reproduction of those carried out in the research of the five questionnaires sent out four suppliers replied over the phone immediately and the final company revealed that questions of such a complex nature could not be answered so readily and that a copy of the question be e-mailed to them so they could deliberate over the answers. At the time of writing this last set of results has not been returned but the author feels confident that this particular company to be proactive in environmental and social issues and would have represented one of the more in depth sets of answers in response to the questions posed.

The names of the companies and persons interviewed has been kept confidential, instead each supplier or manufacturer is represented by the material or materials they supply Trident West with in addition to the position of the person supplying the answers.

#### 5.6.1 Respondent 1: Concrete and Steel - Technical Manager

- i) Do you take into account the amount of embodied energy involved in the process of extracting and producing the materials you manufacture?

- *No.*

Do the materials you manufacture have a recommended or expected life span (how durable are they). If so please answer with regard to materials you provide Trident West with.

- *Yes, 100 years normal 120 years good for pipelines.*

- iii) The next question regards the recycling factors of the materials:
- a) Do you incorporate recycled content into the materials you manufacture; e.g. aluminium %age recycled content.
- *No, but aware of standards that disallow it.*
- b) What percentage of the material is potentially recoverable at the end of its intended use? e.g. concrete is low, aluminium is high.
- *Concrete can be crushed and usually used in land reclamation, and steel reinforcement can go to steel mill or scrap merchant.*
- c) Are you aware of the energy required to recycle the materials at the end of their functional life? e.g. glass is energy intensive.
- *No.*
- iv) If details are not known about the potential recyclability of the materials, are you aware of their waste potential? For example, is the material intended to be discarded at the end of its functional life? (100% waste potential = very unsustainable).
- *Materials are intended to last a very long time although some involved in pipelines that have corrosive substances are subject to planned obsolescence.*

- v) Is the amount of water used in the processing of the material calculated? What is the source of the water supply? (e.g. abstraction, greywater, pipeline etc.)
- *All water used is metered and pipelined in.*
- vi) Do you have a biodiversity plan (or some sort of management) in place? If yes, can you please provide a copy?
- *No, respondent is also Environmental and Quality Manager looking toward ISO 9000 currently then onto ISO 14000.*
- vii) Do you use any CFC's or any other known gases that are detrimental to the ozone layer?
- *No.*
- viii) Do you have a waste minimisation strategy in place? If yes, please provide a copy.
- *Try to reduce waste through the basic aim that waste is bad, but no specific strategy.*
- ix) Do you apply the principles of sustainability (e.g. reduction of raw materials, minimisation of energy use) into your design procedures?
- *Not specifically, just economical factors.*
- x) Do you minimise noise and odour pollution in your production processes? Please give examples.
- *As much as possible, e.g. time constraints near residential areas and systems in place on concrete silos to reduce dust.*

xi) Do you record the origin of your materials, e.g. world, Europe, UK, local?

- *Aggregates and cement are both UK based as was steel until very recently (May be from Europe).*

xii) Are your materials easily repairable e.g. section of pipes or is it less repairable and more replaceable, e.g. brittle plastics.

- *To a certain degree yes, but not always. Repair less than replace.*

### 5.6.2 Respondent 2: Concrete and Steel – Technical Director

i) Do you take into account the amount of embodied energy involved in the process of extracting and producing the materials you manufacture?

- *Yes.*

ii) Do the materials you manufacture have a recommended or expected life span (how durable are they). If so please answer with regard to materials you provide Trident West with.

- *Yes, average life span in line with competitors.*

iii) The next question regards the recycling factors of the materials:

a) Do you incorporate recycled content into the materials you manufacture; e.g. aluminium %age recycled content.

- *Use of virgin aggregates only (Standards prohibit this and are currently under review). Some use of PFA in concrete.*

b) What percentage of the material is potentially recoverable at the end of its intended use? E.g. concrete is low, aluminium is high.

- *Salvageable aggregates and steel reinforcements = 60% by weight.*

c) Are you aware of the energy required to recycle the materials at the end of their functional life? E.g. glass is energy intensive.

- *Crushing and grading a relatively low in energy use.*

- iv) If details are not known about the potential recyclability of the materials, are you aware of their waste potential? For example, is the material intended to be discarded at the end of its functional life? (100% waste potential = very unsustainable).
- *40%.*
- v) Is the amount of water used in the processing of the material calculated? What is the source of the water supply? (E.g. abstraction, greywater, pipeline etc.)
- *Yes water content is carefully measured in concrete, details upon request.*
- vi) Do you have a biodiversity plan (or some sort of management) in place? If yes, can you please provide a copy?
- *Have an environmental committee that however only monitors environmental factors on site (Nothing to do with where materials come from.).*
- vii) Do you use any CFC's or any other known gases that are detrimental to the ozone layer?
- *No, emissions analysis is part of environmental assessment.*
- viii) Do you have a waste minimisation strategy in place? If yes, please provide a copy.
- ix) Do you apply the principles of sustainability (e.g. reduction of raw materials, minimisation of energy use) into your design procedures?

- ?

x) Do you minimise noise and odour pollution in your production processes? Please give examples.

- *Yes, part of ISO 14000 audit; includes the watering down of dust.*

xi) Do you record the origin of your materials, e.g. world, Europe, UK, local?

- *The majority of materials are all sourced from the UK.*

xii) Are your materials easily repairable e.g. section of pipes or is it less repairable and more replaceable, e.g. brittle plastics.

- *Sections of pipe are easily repairable but not allowed due to industry standards.*

### 5.6.3 Respondent 3: Plastic – Principal Engineer

Do you take into account the amount of embodied energy involved in the process of extracting and producing the materials you manufacture?

- *We account for the energy consumed in the manufacture and supply of our polyethylene pipe systems, concentrating primarily on those areas over which we as a business have direct control and hence influence to change. Our activity in this respect covers the following key areas: 1) Product design & development 2) Product manufacture, packaging and storage 3) National distribution (UK) by road haulage In each of these areas we have targeted business policies to reduce our energy consumption and in turn our environmental emissions. In the first section of the supply chain, the extraction of base materials and their processing into a form suitable for supply to manufacturing companies such as ours, we work with a number of chemical companies all of whom have commitments to the environment, covering aspects from energy consumption to recycling of materials.*

ii) Do the materials you manufacture have a recommended or expected life span (how durable are they). If so please answer with regard to materials you provide Trident West with.

- *The materials we supply have a design criteria which stipulates that if they are operated within our recommended industry wide guidance, they will have a service life in excess of 50 years with quantifiable safety factors. After 50 years the safety factor will eventually start to be eroded until such time as it achieves unity*

*and then the potential for failure due to pipe rupture. There are a number of authoritative studies which have now been published, based upon theoretical prediction and actual data dating back to the mid 1950's which confidently predict lifetimes in excess of 100 years at the rated design pressure.*

The next question regards the recycling factors of the materials:

- a) Do you incorporate recycled content into the materials you manufacture; e.g. aluminium %age recycled content.
  - *Where material has been generated within the confines of our own manufacturing site and is deemed unfit for sale (e.g. scrap generated through manufacture, product damaged in stock, etc.) then this material is granulated and provided it has not been recycled already, can be reprocessed into new pressure pipes suitable for use with potable water and no loss of long term properties. Where material has been generated within the confines of our own manufacturing site and it has been recycled once already, then it is granulated and reprocessed into new pipes of a lower performance level, such as might be appropriate for gravity drainage applications.*
- b) What percentage of the material is potentially recoverable at the end of its intended use? e.g. concrete is low, aluminium is high.
  - *All the material is recoverable. It can be granulated, a new additive package can be added if required and it can be reprocessed. This currently happens with a range of companies offering to take material waste generated during site construction*

*activities and pipe removed from the ground, and reprocessing this into a range of products, some of which may be pipe or duct products, some of which are general plastic products for other domestic and industrial uses.*

- c) Are you aware of the energy required to recycle the materials at the end of their functional life? E.g. glass is energy intensive.
- *The energy required is the same energy we use to form the product, essentially melting, shaping and cooling the material. The procedure can be repeated many times to recycle the product.*

If details are not known about the potential recyclability of the materials, are you aware of their waste potential? For example, is the material intended to be discarded at the end of its functional life? (100% waste potential = very unsustainable).

- *The material can all be recycled. Some components such as electrofusion fittings which contain brass wire may not be suitable for shredding and reprocessing into new extruded or moulded products unless a metals separation device is used in the extruder unit, technically possible but not always implemented. In such cases the material is usually sent for incineration allowing the stored energy to be recovered.*

Is the amount of water used in the processing of the material calculated? What is the source of the water supply? (e.g. abstraction, greywater, pipeline etc.)

- *The water used for cooling the material is stored in a sump tank at the plant and is recycled continuously through on site chiller and filtration units. When the tanks require topping up to allow for vapour evaporation then water is drawn from piped water supplies to the plant, which are metered.*

Do you have a biodiversity plan (or some sort of management) in place? If yes, can you please provide a copy?

- *I do not think that we have such a plan.*

Do you use any CFC's or any other known gases that are detrimental to the ozone layer?

- *No CFC's utilised in our product processes. Pipe is distributed by road haulage and we have examined and attempted to quantify the emissions of the haulage contractors who operate on our behalf. As part of our review with have a plan implemented in 2001 to move over to LPG powered vehicles, of which we currently have six, to reduce these emissions.*

Do you have a waste minimisation strategy in place? If yes, please provide a copy.

- *Our strategy is focussed around the following key points: 1) we seek to minimise machine changeovers and wastage generated through start up in manufacturing. This has involved a long-term commitment to a new pipe product range that minimises the requirements for purging materials from extruders each time a product change occurs for a different sector of the industry. We*

*then aim to minimise product wastage during start up of extrusion equipment and obtaining in specification product through the procurement of new manufacturing equipment and training and organisation of operatives. 2) Where material waste is produced we recycle 100% of this as stated above, into the same or lower performing products. 3) We implemented commitments to reduce packaging waste associated with our products by using recyclable pipe coil dispensers rather than stretch wrapping, using recyclable bulk delivery containers, etc. This commitment continues and is undertaken in partnership with customers. 4) Any packaging materials associated with our incoming materials is segregated (i.e. wood/pallets, plastic films, etc) and recycled.*

Do you apply the principles of sustainability (e.g. reduction of raw materials, minimisation of energy use) into your design procedures?

- We have for a number of years moved towards the design and production of thinner walled products, both pipe and fittings, as advances in material technology allow us. This has a benefit of reducing the material requirements for our products, which in turn reduces the energy required for conversion. This is the current level of policy implementation in this respect.*

Do you minimise noise and odour pollution in your production processes?

Please give examples.

- Noise and air pollution are controlled in our production processes to meet best practice requirements of the UK HSE. There are minimal emissions in terms of fume from hot raw materials and*

*the production processes are relatively quiet. We do not require special breathing apparatus for employees working in the vicinity of machines and ear protection is voluntary being below levels considered hazardous.*

Do you record the origin of your materials, e.g. world, Europe, UK, local?

- *All materials are fully traceable through to source as part of our QA (Quality Assurance) system.*

Are your materials easily repairable e.g. section of pipes or is it less repairable and more replaceable, e.g. brittle plastics.

- *The material which we supply is polyethylene which is a plastic and highly ductile. Where pipelines are damaged usually through third party in interference they can at the discretion of the asset owner remain in service with the damage component, be subject to a localised repair which may be a short or long term solution, or have an isolated section cut out and replaced. Typically a PE pipe can sustain 10% wall damage without affecting the design life; more extensive damage can be traded against a reduced design life or more usually a reduced maximum operating pressure if this is allowable within the network design. Repair clamps are available for temporary repair of short lengths of damaged pipe and for more extensive lengths it is possible to cut out and replace the damaged section. The damaged pipe can then be recycled if required.*

#### 5.6.4 Respondent 4:– Concrete - Technical Supervisor

- i) Do you take into account the amount of embodied energy involved in the process of extracting and producing the materials you manufacture?
- *No.*
- ii) Do the materials you manufacture have a recommended or expected life span (how durable are they). If so please answer with regard to materials you provide Trident West with.
- *No specific recommendations but in pipes that don't contain aggressive chemicals should last at least 60 years if not 100 years.*
- iii) The next question regards the recycling factors of the materials:
- a) Do you incorporate recycled content into the materials you manufacture; e.g. aluminium %age recycled content.
- *No, due to industry standards (But use them elsewhere if possible).*
- b) What percentage of the material is potentially recoverable at the end of its intended use? e.g. concrete is low, aluminium is high.
- *Pipelines are usually filled in and left or used as fill material.*
- c) Are you aware of the energy required to recycle the materials at the end of their functional life? e.g. glass is energy intensive.
- *No.*

- iv) If details are not known about the potential recyclability of the materials, are you aware of their waste potential? For example, is the material intended to be discarded at the end of its functional life? (100% waste potential = very unsustainable).
- *Pipes are usually left underground at the end of life. Costs less to do this.*
- v) Is the amount of water used in the processing of the material calculated? What is the source of the water supply? (e.g. abstraction, greywater, pipeline etc.)
- *Yes the mains supply is metered.*
- vi) Do you have a biodiversity plan (or some sort of management) in place? If yes, can you please provide a copy?
- *Not specifically but have an environmental policy.*
- vii) Do you use any CFC's or any other known gases that are detrimental to the ozone layer?
- *No.*
- viii) Do you have a waste minimisation strategy in place? If yes, please provide a copy.
- *Nothing written down but the company strives to be efficient.*
- ix) Do you apply the principles of sustainability (e.g. reduction of raw materials, minimisation of energy use) into your design procedures?
- *Only to achieve economic efficiency.*

x) Do you minimise noise and odour pollution in your production processes? Please give examples.

- *Yes, have a duty of responsibility to meet local standards. Cement Silo filters are very good.*

xi) Do you record the origin of your materials, e.g. world, Europe, UK, local?

- *UK mostly, all the rest from reputable sources.*

Are your materials easily repairable e.g. section of pipes or is it less repairable and more replaceable, e.g. brittle plastics.

- *Those pipes in service are not normally repairable. However, those that are damaged in manufacture are reworked.*

## Appendix B

The following information is some of that leveraged from meetings with TWA staff members. Here information from the Design Manager, Senior Design Engineer and Site Manager is summarised.

### (Design Manager)

- Introduction to design practices in MWH and Trident West.
- Took over from previous Design Manager recently.
- Looked at possible prioritisation of construction under the following headings:

1. *Pipelines*
2. *Tanks/Chambers*
3. *Plant/Equipment*
4. *Buildings/Enclosures*
5. *Electrical/C&I*
6. *Infrastructure*
7. *Other*

1. *Pipelines:*

Most of the pipelines are made from PVC and are relatively homogeneous. They represent a very small financial input by Trident West and are ranked number 6 in economic impact.

2. *Tanks/Chambers*

The tanks and chambers are one of the most numerous structures constructed in the Trident West Agreement. They are constructed from mostly concrete and steel, sometimes Glass Reinforced Plastic (GRP). These units are also built both above and underground. Tanks and chambers represent the greatest economic impact out of all the categories and could have a good potential to move away from unsustainable building practices. Some of the tanks and chambers are made from substitute materials such as brick, and ash is already used in the concrete used (Maybe potential to use sewage sludge here? WW states that this would not be hard to try.) Any excavated soil is also kept on site (try not to disturb trees and if so they are replaced).

3. *Plant/Equipment:*

These include pumps/scrapes/weirs/water treatment plants.

4. *Buildings/Enclosures:*

These include the provision of covers for the tanks and chambers. The covers consist predominantly of GRP, which is relatively quick and easy to use. It arrives in one pre-cast piece and can be put in place very quickly. The potential for re-use is existent, as many of the caps are homogeneous in size and specification. The materials all come from UK based firms and GRP also has the added element of being very secure and resistant to vandalism and break-ins in accordance with company H&S regulations with particular reference to people falling at installations being the major issue. About 5-10% of projects also use steel frame buildings with cladding, e.g. clean water products for nitrate removal. WW comments that this area should be avoided?!?! (Low economic ranking)

## 5. *Electrical/C&I*

Cabling outside and plant equipment, e.g. generators inside. Control and instrumentation – how the site is controlled and linked to the national grid. Generators are an area of interest by themselves, often used only on a top-up basis. Talk to Thames Environment Manager (Annette).

## 6. *Infrastructure*

This area includes items including roads, etc. Recycled tyres are used as a substrate in roads (Local Authorities?)

- See copy of matrix.

## **Other Issues**

- Energy in projects is mostly cost driven. Must however be energy efficient – from a variety of sources
- Thames procurement could be more sustainable
- Security is the biggest issue with timber (Arson and Durability)
- Everything done has a process code, e.g. by treatment stage (1,2,3) (Also 1.1, 1.2, 1.3 etc)
- Close loop on sludge burnt = energy (Climate change levy) ([http://www.incogroup.com/ccl\\_page2.html](http://www.incogroup.com/ccl_page2.html))
- Thames are better at the 'more visible' issues
- 3-9 months between design and projplan and EIA and building
- Initial environ and quality screening – good and well run includes wildlife and habitats – Spider diagrams to review these processes or results
- FRAMEWORK AGREEMENT
  - Cost is the deciding factor for all materials
  - Decisions for which are made above WW
  - Framework agreement (2,3,5 years) (Thames)
  - Joint alliance between Laing and Gleeson
  - POTENTIAL FOR SUSTAINABILITY AND DESIGN!!!!!!!!

## **(Senior Project Designer)**

- The need for tools to assess materials in terms of their sustainability is needed. Sometimes situations arise where two materials are available for a job and both cost the same and have the same technical specification. How do I choose which one is most sustainable?

## **(Site Manager)**

- Economist/Civil Engineer background
- Asked questions based around MWH's current status on sustainability indicators sheet
- Looking at issues of: Site Appraisal & Design, Processes & Construction

## **1.0 Recycling/Re-using Materials:**

### **1.1 Assessment of scope for using recovered/recycled materials:**

- Materials are ordered as and when needed – Often in stages. (More journeys?)
- Mechanical equipment obviously has longer lead times though.
- Avg. 10% waste for brickwork at a site.
- Left over materials are often re-used elsewhere.
- Old materials → Backfill soil for pipelines, e.g. shingle, ballast or coarse sand. Only those found on site though or an extraction licence (From EA?) is required.
- They re-use ground.

### **1.2 Scope for/Plans to recover materials at decommissioning:**

- Plans afoot to recover materials at decommissioning stage of a site.

### **1.3 % of timber used in construction from well managed sustainable sources**

- Timber is used a lot in concrete pouring and in scaffolding.
- Need to talk to procurement about if it is from well-managed sources. Also speak to carpenters and general foreman.
- No compromises on H&S and have ISO 14000 (Contractors need to be very good!)
- People = P.K. Site manager for Constructors. And also M.L. - Site agent (Has potential for sustainability (Financial pressure is on him)).

### **1.4 Actual use of materials from sustainable sources (e.g. secondary or recycled)**

- Some!
- Pre-Fab manhole boxes – 100% recycled! (Not all boxes though).
- Less than 1% of all materials in above example they happened to be the cheapest.
- Masonry block work.
- Bricks, etc get re-used when too many are ordered.

## **2.0 Waste Minimisation**

### **2.1 Knowledge of legal obligations with regard to waste:**

- Speak to P.K. site manager – he has the knowledge.
- Hauliers collect waste – Trust the reputation of the disposer.

### **2.2 Has the project got a waste minimisation strategy:**

- A strategy is incorporated into environmental policy.

### **2.3 Final disposal of waste:**

- Timber goes into timber skips (For re-use?!?!).
- Special skips for hazardous materials.
- Scrap metals skip.

### **2.4 CO<sub>2</sub> released from construction activities:**

- No! Noise is the most measured form of pollution.

### **3.0 Energy**

#### **3.1 Has the project incorporated renewable energy systems or combined heat and power:**

- Not sure, speak to B.B. – Electrical Engineer.

#### **3.2 Energy use at fixed sites – Energy use per MI of water supplied, Energy use per MI of waste-water treated:**

- No idea.

### **4.0 H<sub>2</sub>O Efficiency and Quality**

#### **4.1 Water consumption m<sup>3</sup> per £ turnover arising from construction site activities:**

- Water supply comes from existing site sources – Speak with M.L. the site agent.

#### **4.2 Features to encourage people to save water:**

- ?

#### **4.3 Breaches of consent:**

- Infrequent or accidental only, e.g. diesel leaks.

#### **4.4 River water quality – River length in classes A-D:**

- Don't know.

#### **4.5 Waste water treatment works:**

- Don't know.

#### **4.6 Water metres installed and working:**

- ?

### **5.0 Noise, Nuisance, Air & Odour**

#### **5.1 Odour:**

- Looked at already.

#### **5.2 Minimisation of noise during construction:**

- 7.30 am machines start, 8.00 am Sat & Sun.
- Varies from site to site, e.g. rural or urban locations.

#### **5.3 Emissions of Methane, SO<sub>x</sub> & NO<sub>x</sub>:**

- Chlorine, SO<sub>2</sub>, Ozone

#### **5.4 Minimisation of noise during operation:**

- Regulations in place for pumps and generators.

## **6.0 Natural Light and Lighting**

### **6.1 Use of natural light:**

- Not usually at unmanned sites.
- Windows are a big H&S issue.

### **6.2 Use of low energy heating and lighting:**

- Some energy saving bulbs.
- Lighting is contracted. (Put pressure on contractors?!?!)

## **7.0 H&S**

### **7.1 Has the project reported fatal and non-fatal accidents:**

- Yes – deaths, near misses. Everything.

## **8.0 Sustainability**

### **8.1 Durability and adaptability of building assessed:**

- Buildings typically have a life span of 25-30 years.

### **8.2 How reversible is the project:**

- No design for disassembly.
- However, the site is as compact as possible.

## **9.0 Environment**

### **9.1 Any formal environmental/nuisance notices served:**

- Don't know.

## **10.0 Involving the Local Community**

### **10.1 Has the project included and implemented a plan for stakeholder dialogue:**

- Yes.

### **10.2 Has the project included and implemented a plan to consult with the end user:**

- Yes.

### **10.3 Dissemination of construction activities to the public:**

- Yes.

### **10.4 Other options for developments considered:**

- Yes, other types of treatment works considered.

## **11.0 Wildlife & Habitats**

### **11.1 Species and Habitats – Have you considered any priority species and long term action plans:**

- Yes. Speak to P.J. at MWH.
- Also see water Vole report.

## **12.0 Landscape**

### **12.1 Natural Treatment – SUDS:**

- ?

### **12.2 Preservation of topsoil and avoidance of subsoil compaction:**

- Various routes for vehicles not just one.
- Landscape is worked on and looks much better after completion of the project.

## **13.0 Transport**

## **14.0 Training, Skills & Development**

### **14.1 Internal project awareness of sustainability:**

- Yes!

### **14.2 Promotion & training of sustainability to suppliers:**

- The responsibility of the construction company.

## **15.0 Using Local Labour**

### **15.1 Reasons recorded when not using local contractors:**

- The construction company in the TWA is in charge of all procurement.

### **15.2 Any complaints about site employees:**

- No.

### **15.3 Any small pieces of work that could be carried out by the community:**

- Not really as it is a H&S issue.

## **16.0 Using Local Materials**

## Sustainability Impacts – M<sup>2</sup> Construction Materials

[illegible]

