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A FRAMEWORK FOR MANAGING SUSTAINABILITY KNOWLEDGE, THE C-SAND APPROACH

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ABSTRACT

There has been growing awareness of the importance of sustainable development and sustainable construction around the globe for the last few decades. Sustainable development can be defined as the development, which meets the needs of the present without compromising the ability of future generation to meet their own needs. Sustainable construction is the application of sustainable development practices to the construction industry domain. In this field and despite governmental strategies and initiatives, much more has to be done to make construction more sustainable and achieve the targets set for sustainable developments. One of the major obstacles is to capture and manage the knowledge required to improve sustainability in construction. To support this there is a need for a framework to incorporate sustainability issues within the whole construction process including pre- and post- construction phases.

After a comprehensive literature review on sustainable development and sustainable construction, the paper presents current practice and perception of sustainability within the industry based on field work conducted as part of the C-SanD Project (Creating, Sustaining, And Disseminating Knowledge For Sustainable Construction: Tools, Methods And Architectures) interviews, with a focus on creating and sharing knowledge for sustainable development and sustainable construction. Finally we present a framework to support the implementation of sustainable construction practices based on a generic design and construction process (Process Protocol).

KEY WORDS

Sustainable Development, Sustainable Construction, Knowledge Management, Construction Industry.

1. INTRODUCTION

Awareness of the importance of sustainable development has been growing around the globe for the last few decades. The 'Agenda 21', the closing document of the UN 'Earth Summit' in 1992 in Rio de Janerio (http://users.whsmithnet.co.uk/ispalin/a21/); the Kyoto protocol for reduction in greenhouse gas emissions (http://unfccc.int/resource/convkp.html), and many other international and national initiatives show the growing concern for protecting the environment for the future generations by introducing sustainable development concepts (Parkin, 2000). This paper gives an overview on sustainable

development and sustainable construction, based on a comprehensive literature review, followed by current practice and perception of sustainability within the industry based on field work conducted as part of the C-SanD Project. Finally, a framework is presented to support the implementation of sustainable construction practices based on the Process Protocol, which is a generic design and construction process tool (Process Protocol, 1998).

2. SUSTAINABLE DEVELOPMENT

There are many definitions for sustainable development, a few of them are reviewed here. According to Sage (1998), sustainable development refers to the fulfilment of human needs through simultaneous socio-economic and technological progress and conservation of the earth's natural systems. Sustainable world progress is dependent upon continued economic, social, cultural, and technological progress. To achieve this, careful attention must also be paid to preservation of the earth's natural resources. Sustainable development is a term generally associated with the achievement of increased techno-economic growth coupled with preservation of the natural capital that is comprised of environmental and natural resources. It requires the development of enlightened institutions and infrastructure and appropriate management of risks, uncertainties, and information and knowledge imperfections to assure intergenerational equity, intragenerational equity, and conservation of the ability of earth's natural systems to serve humankind (Sage, 1998). Chaharbaghi and Willis (1999) presented different perspectives of sustainable development, illustrated in Figure 1, which shows different views from different professionals.

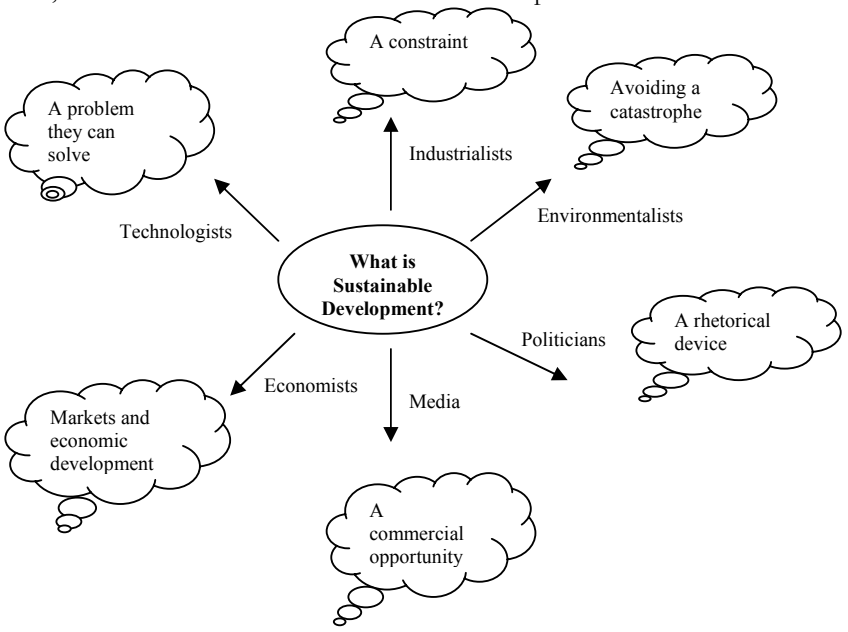

Figure 1: Images of Sustainable Development (Chaharbaghi and Willis, 1999)

DETR (2000) argue that sustainable development is all about ensuring a better quality of life for everyone, now and for generation to come, through:

- Social progress which recognises the needs of everyone;
- Effective protection of the environment;
- Prudent use of natural resources; and
- Maintenance of high and stable levels of economic growth and employment.

There is also a common definition for sustainable development, which was formulated by the World Commission on Environment and Development (WCED), led by the Norwegian Prime Minister Gro Harlem Brundtland, in 1983. It states that "…Sustainable development is development, which meets the

needs of the present without compromising the ability of future generation to meet their own needs" (Chaharbaghi and Willis, 1999).

Sustainable development includes three broad components; social, environmental, and economic; often known as the 'triple bottom line', as shown in Figure 2. The next section focuses more on the application of sustainable development within the construction industry.

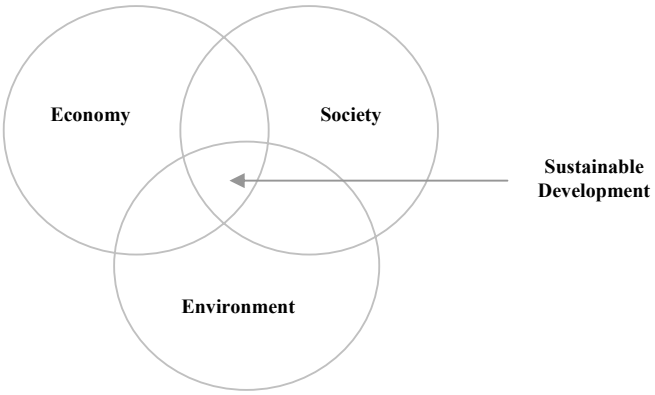

Figure 2: Themes of sustainable development

3. SUSTAINABLE CONSTRUCTION

Sustainable construction could be defined as "…The creation and responsible management of a healthy built environment based on resource efficient and ecological principles". Sustainable construction is generally used to describe the application of sustainable development to the construction industry. The construction industry is defined as all who produce, develop, plan, design, build, alter, or maintain the built environment, and includes building material suppliers and manufacturers as well as clients, end users and occupiers. Therefore, sustainable construction could be best described as a subset of sustainable development, which encapsulates matters such as design, tendering, site planning and organisation, material selection, recycling, and waste minimisation (Langston and Ding, 2001).

There are six main principles for sustainable construction, presented by Y. Miyatake (1996):

1. Minimisation of resource consumption;
2. Maximisation of resource reuse;
3. Use renewable and recyclable resources;
4. Protect the natural environment;
5. Create a healthy and non-toxic environment; and
6. Pursue quality in creating the built environment.

And there are three suggested ways by which the construction industry can act to realise the above mentioned principles of sustainable construction (Miyatake Y., 1996):

- Creating a built environments for a better/improved quality of life;
- Restoring damaged and/or polluted environments; and
- Improving arid environments.

Miyatake (1996) also suggests that everybody has to realise that in order to achieve sustainable construction, the industry must change the processes of creating the built environments. This could be coined as bringing change from linear processes to cyclic processes within the construction industry. This means that the industry has to change the way in which all the construction activities are undertaken. The industry is using energy, material, and other resources to create buildings and other civil engineering projects, and one of end results of all these activities is a huge volume of discharge waste during and at the

end of the facility's life. Therefore, changing this linear process into a cyclic process will bring increased use of recycled, renewed and reused resources, and a reduction in the use of energy and other natural resources.

In the UK, and according to CIRIA (2001), the construction industry is recognised for having major economic (the industry accounts for 8% of UK GDP), social (the sector employs 1.4 million people) and environmental (30% of UK controlled wastes result from the construction process) impacts. The UK Government is working towards enhanced quality of life for the people, improved customer satisfaction, and increased potential to cater for user changes in the future. The Government also wants to provide and support desirable natural and social environments, and maximise the efficient use of resources (Raynsford, 2000). In order to achieve all the above, the Government signed an agreement in 1992 at the Earth Summit in Rio de Janerio to implement Agenda 21, which was then followed by appointment of a Panel on Sustainable Development. In 1997, the Construction Industry Environment Forum was launched. Furthermore, the Egan Report 'Rethinking Construction', published in 1998, resulted in the launch of the M4I initiative, the formation of the Construction Confederation, and the Construction Best Practice Programme. There is also a Sustainability Action Group within the Government Construction Client's Panel (Raynsford, 2000).

In this respect and despite recent governmental strategies and initiatives, much more has to be done to make construction more sustainable and achieve the targets set for sustainable developments. One of the major enablers for this is to create, capture, manage, and disseminate knowledge required to improve sustainability in construction. For this to be achieved, an EPSRC-funded research project 'C-SanD' (Creating, Sustaining, And Disseminating Knowledge For Sustainable Construction: Tools, Methods And Architectures) commenced in July 2001 involving Loughborough, LSE and Salford Universities to look into the above issues with the help of leading construction client, contracting and consulting organizations. The next section gives a brief description of the project.

4. THE C-SanD PROJECT

4.1. Background

To attain the goals of sustainable construction requires that the industry intensify its efforts to move to a knowledge intensive mode. Sustainability goals can only be achieved if construction activities are informed by new resources of knowledge and expertise. Some of this comes in the form of good practice, standards and enhanced process models, but much will have to come from situated and contextual appreciations of sustainability goals and local practices developed across organisational and professional boundaries. To achieve this requires the industry to focus on and achieve new modes of knowledge management, including embedded knowledge creation. Therefore, this need for knowledge creation within a sustainability context is the main focus of this project.

Over the last decade, construction companies have invested heavily in the improvement of their business processes. New forms of innovative project management, supported by IT, appeared as a response to the ever-growing pressure from clients to deliver high quality facilities on time and on budget. Through this a new activity emerged from the process of managing projects and became a focus of interest: that is the one of knowledge management.

Despite the interest and the effort put into knowledge management by many leading companies, the discipline is still in its infancy. Many practitioners and researchers have acknowledged the limitations of current approaches to managing the information and knowledge relating to and arising from a project. Among the key reasons for these limitations are:

- Much construction knowledge, of necessity, resides in the minds of the individuals working within the domain.

- The intent behind decisions is often not recorded or documented. It requires complex processes to track and record the thousands of ad-hoc messages, phone calls, memos, and conversations that comprise much project-related information.
- Data is captured during a project and archived at the end of a project, this is necessary but not sufficient for knowledge systems. Knowledge is created by people actively reflecting on the events represented by the project data. The knowledge gained is often poorly organised and buried in details, and there are seldom processes in place for the required reflection. Hence, it becomes difficult to compile and disseminate useful knowledge to other projects.
- People frequently move from one project to another, so it is difficult to track the people who were involved in a recorded decision and who understand the context of the making of the decision and its implementation.
- New approaches to the management of knowledge within and between firms imply major changes in individual roles and organizational processes. While the potential gains are desired, the necessary changes are resisted.

Experience shows that there are difficulties in capturing, storing, sharing and re-using all the information and knowledge relating to and arising from a project in the construction sector, assuming that it exists, but much of it is never 'produced', since no mechanisms or processes exist to foster the social interaction required to give any shape of form to it. The main focus of the project is therefore to develop organisational practices in the construction sector to promote knowledge creation, prior to sharing and re-use, along with the tools to support such a process. The knowledge domain that the work will focus on is the promotion of sustainable development in the construction industry in areas such as the minimisation of waste, materials recycling and energy conservation in the design, construction and operation of buildings (http://www.c-sand.org.uk/).

4.2. Project Aim and Objectives

The overall aim of the project is to foster organisational practices in the construction industry which enable knowledge creation for subsequent sharing and re-use, and to promote sustainable development. Incremental development and implementation of knowledge management tools will be carried out using a 'bottom up' soft systems methodology (SSM). This is intended to support situated, contextual knowledge creation processes. This aim translates into the following associated objectives:

- Analyse knowledge creation practices of two of C-SAND industrial partners and model the project and organisational knowledge of two construction projects, as well as contractual and legal aspects related to knowledge sharing within and between partners and projects;
- Specify a model-based infrastructure (including a dedicated set of services packaged in the form of an API) that supports creating and sharing of project and organisational knowledge in general, and knowledge related to sustainability in particular, in an environment which recognises complex intellectual property rights and confidentiality issues;
- Develop a framework that facilitates the processes of knowledge creation and re-use at project and organisational level with a focus on sustainability in design and construction;
- Develop “low entry level” tools (affordable and with high usability so that a small company can join larger firms) to create, capture, and re-use project knowledge with the goal of promoting sustainable development; and
- Implement and evaluate tools in a real life context and from these cases produce organisational recommendations in the form of a roadmap and/or a diagnostic grid of potential risks and stages in adopting the proposed approach.

4.3. Methodology

This project is concerned with developing knowledge management (KM) approaches, architectures and tools within a contextually sensitive appreciation of sustainability in design and construction. The primary

focus of the project is knowledge creation (KC), the potential means by which project experience, organisational practices, environmental influences and imperatives, formal and informal skill sets come together (through technical, organisational and social modalities) to produce new resources of knowledge upon which industry participants can draw. In such an approach knowledge is not seen as a 'raw material' just requiring refinement and packaging prior to distribution, but as requiring its own 'production processes' drawing together different streams of experience and skill and developing within the different but interconnected modalities.

The project is based on extensive field research and use the following:

- continuous review of the academic, industrial and web-based literature to maintain awareness of current developments;
- case studies of knowledge creation within the collaborating companies, using observation and questionnaires, supplemented with semi-structured interviews;
- a prototyping approach to develop the Knowledge Infrastructure Models; and
- iterative user-and expert-based evaluation of the model and its support tools.

The project methodology is based on a combination of Soft Systems Methodology for organisational analysis; and incremental and iterative OO (Unified Modelling Language) modelling for technical components. From the social and organisational pole the research will draw on contextually rich modelling techniques including Checkland's Mode 2 SSM (Soft Systems Methodology) (Checkland, 1981) with its emphasis on a stream of cultural analysis, involving reflection on the social system, the political system and the intervention itself. SSM will provide a framework for integrating and reconciling diverse views on an issue as complex as sustainability through the generation and exploration of multiple root definitions of the issues. This will mitigate the risk of building a system which will be robust in its own terms but will not be aligned with the ways of working of the firm and the industry. This will be complemented by incremental and iterative based OO (UML) modelling for technical components. UML, and in particular the application of use-cases and object sequence diagrams, will allow an approach to the building of knowledge systems which is driven by user needs, user roles (actors) and user understandings of the issues identified through the SSM analysis. This is in contrast to a view of knowledge systems which is top down and organisationally limited.

4.4. Initial Project Findings

The project began by interviewing senior management within the collaborating industrial organisations. The first stage of the field work consisted of 16 interviews within ten organisations undertaken by four researchers from three universities. A SSM approach was adopted by the researchers and rich pictures were produced. These multiple rich pictures represented overlapping and contrasting concepts and presented such richness that it was impossible to gain a satisfactory overall picture. Therefore, the Oval Mapping Technique from Eden and Ackermann (1998) was adopted, which enhanced interaction and promoted further discussion. The discussion resulted into nine clusters each including between four and seventeen concepts. These clusters have now been used to identify issues that can be modelled through one or more CATWOEs (Customers, Actors, Transformation, Worldview, Owner, and Environmental constraints) and through root definitions (that express the core purpose of purposeful activity system) as defined in SSM (Checkland, 1981; Checkland and Scholes, 1990). The next step from here would be transferring these CATWOEs into UML for the start of the primary modelling of the project.

This section presents some of the ‘sustainability’ issues which were identified within the participating companies after the first round of the project interviews and their analysis. The participating companies came up with different individual and organisational perceptions and definitions of sustainability. The most common concepts were: linking sustainability with environmental issues, inter-connected nature of sustainability with value engineering and knowledge management, and energy efficiency. There was a consensus that all construction activities damage the environment, therefore, there is a need to limit this damage, not only to the environment, but also the society and economy. Another common question

which came out of the interview analysis was, 'At what stage should sustainability be considered?', and the agreement was that sustainability should be built-in within a project and should not be bolt-on. However, how it can be built-in was another question raised.

Analysis also revealed that different sustainability aims were in conflict with each other. For example sustainability sometimes requires costly innovation that conflicts with limited budgets, and hence limiting client's motivation towards sustainable construction. There were other issues highlighted during the interviews including waste reduction on construction sites which can be achieved through off-site construction; project de-commissioning; management of sustainability knowledge i.e. its creation, transfer, use, storage, etc.; and weakness of Whole Life Cost (WLC) models (that can demonstrate long term benefits of sustainability) which results in giving priority to capital cost over operational cost.

There were few requirements identified by the interviewees that are needed to promote sustainable construction. These include the introduction of sustainability into the design in order to encourage sustainable behaviour by the clients and end users; incorporating sustainability in a daily routine on projects in order to make it a regular practice by the whole construction supply chain; a system that demonstrate sustainability impacts of day to day work on a construction projects; and using sustainability criteria for the selection of sub-contractors, materials, etc.

Drivers and enablers of sustainable construction were also discussed. Client and community awareness were the most significant drivers identified by the participating construction firms. Motivated clients can steer the industry to deliver sustainable construction projects and clients' interest could be developed with the help of new tools and techniques, demonstrating benefits of sustainable construction. On the other hand, the industry needs guidance by the Government in the form of regulations and legislations, which would drive the industry towards sustainability. Another driver to sustainability is the use of new procurement methods such as Private Finance Initiative (PFI), Design, Build & Operate, etc., in which the developer is responsible for maintaining the facility for 25 to 50 years, resulting in the realisation of the low operational cost that can be achieved through sustainable construction. Increased competitiveness through labels such as 'Green Firm' or having 'FTSE4Good' badge are also major drivers towards sustainable construction. Some of the clients and contractors are also using sustainability as a marketing tool for their companies to win more projects.

One of the important issues identified in the interviews is to integrate sustainability within the whole life cycle of a building from design to construction and operation. To respond to this the project team decided to map sustainability issues on a generic project process (Process Protocol) to identify actions to be undertaken at different stages of the building life cycle in order to achieve sustainable goals.

5. A FRAMEWORK FOR SUSTAINABLE CONSTRUCTION

The Process Protocol is a generic process map for design and construction. Its basic purpose is to provide a framework for carrying out any construction project. It is essentially a common set of definitions, documentation and procedures that provides the basis to allow a wide range of organisations involved in a construction project to work together seamlessly. It uses manufacturing experience as a reference point and maps the entire project process from the client's recognition of a new or emerging need through to operations and maintenance (Lee et. al., 2000). The design and construction process is mapped by breaking it down into eight sub-processes, namely Development, Project, Resource, Design, Production, Facilities, Health & Safety and Legal, and Process Management. The whole construction process was divided into four broad stages; pre-project, pre-construction, construction, and post-completion, and ten phases (Process Protocol, 1998; http://pp2.dct.salford.ac.uk/). Some of the potential advantages of adopting the Process protocol as the industry standard are (Lee, 2000):

- It provides a whole project view;
- It recognises the interdependency of activities throughout the whole project;
- It focuses on the identification, definition, and evaluation of client's requirements;

- It enables co-ordination of the participants and activities in construction projects and identifies the parties responsible;
- It encourages the establishment of multi-functional teams; and
- It encourages a team environment, and appropriate and timely communication and decision making.

Work is being conducted at Loughborough University to map sustainability issues within the design and construction phases of a project as defined in the Process Protocol. The aim is to develop a checklist of sustainability-related issues, which should be addressed during each of the ten phases of the Process Protocol framework. The main purpose of this exercise is to make sustainability one of the management areas within Process Protocol, which would then drive all construction projects towards sustainable construction practices (see Table 1).

Table 1 describes the proposed framework towards sustainable project development. For example, Phase four of the Process Protocol framework, under pre-construction, covers Outline Conceptual Design, the different tasks carried out during this phase should be conducted to include sustainability guidelines. Tasks such as reviewing different alternative designs should also include a sustainability assessment of each alternative. List of all the suppliers should be prepared and reviewed with respect to material's quality, re-cycle-ability, etc. Cost plans and procurement plans should be prepared and reviewed considering sustainable construction criteria as identified. And the final alternative should be decided, based on which alternative is the most sustainable one.

6. CONCLUSION

This paper presented a brief overview into sustainable development and sustainable construction concepts, followed by an introduction to the C-SanD project and its initial findings related to current practice and perception of sustainability within the construction industry based on a first round of interviews. In the later part of the paper, a need for incorporating sustainability within the whole construction process was identified and resulted in the incorporation of these issues within the Process Protocol, which is a generic design and construction process map. The ongoing work needs to consider the whole supply chain within the construction industry to achieve a more sustainable construction. An important aspect is that sustainability issues are sometimes ignored or overlooked during the whole process of project development. Therefore, there is a need for a checklist to enable participants to consider sustainability as part of project development. This checklist should include broader aspects of life, for example ethical characteristics, morale and vision of a community. These aspects have already been identified by Lombardi (2001) and could be applied to the Sustainability-Process Protocol framework. This proposed work will be undertaken as part of the next phase of the C-SanD project.

Table 1: PROCESS PROTOCOL PHASES: SUSTAINABILITY APPROACH

PHASES	GOAL(S) PHASE	GOAL(S) SUSTAINABILITY	PHASE ACTIVITIES	SUSTAINABILITY CONSIDERATIONS
PHASE ZERO - Demonstrating the need *'What is the problem?'*	- Identify needs & how to fulfil those need.	- Understanding sustainability issues - Fulfilment of needs also benefit sustainability themes	- Consultant appointment - Master plan production - Initial funding approval	- Consider alternatives e.g. refurbishment - Study cost, benefit & risk associated - Obtain client's commitment for sustainability
PHASE ONE - Conception of need *'What are the options and how will they be addressed?'*	- Recognise & choose potential options	- Choose sustainable options	- Cost, benefit, and risk analysis - Update project deliverables - Consider procurement & management options	- Consult environmental expert - Recommendation on sustainable options - Follow environmental legislation - Prepare sustainability policy
PHASE TWO - Outline Feasibility *'Which option(s) should be considered further?'*	- Identify best solutions for feasibility study	- Choose the best sustainability options	- Project team appointment - Procurement route decision - Feasibility study - Prepare project brief - Planning & management - Criteria for selecting option - Define CSFs for project evaluation	- Identify Sustainability Critical Success Factors (CSFs) - Sustainability commitment among team - Conduct Environmental Impact Assessment (EIA) and - Prepare Environmental Management System (EMS) - Consider whole life cycle in design options - Prepare cost estimation
PHASE THREE - Substantive Feasibility Study & Outline Financial Authority *'Should the proposed solution(s) be financed for development?'*	- Decide best option for substantive study	- Choose the most sustainable choice	- Substantive feasibility - Prepare & update deliverables - Key criteria for design evaluation - Identify suppliers/contractors - Statutory & financial approval - Decide option	- Compliance with sustainability criteria - Conduct environmental assessment - Ensure Local community involvement - Sustainable suppliers selection - Sustainable contractors selection
PHASE FOUR - Outline Conceptual Design *'How does the solution translate to an outline design?'*	- Identify different design options - Decide best design	- Select sustainable design	- Identify design alternatives - Develop schematic design - Use criteria to review design	- Decide sustainability design elements - Identify sustainable materials - Compliance with regulations - Coordination & transfer of information - Prepare cost & procurement plan - Identify suppliers for sustainable materials
PHASE FIVE - Full Conceptual Design *'Can we apply for planning permission?'*	- Complete design for planning approval	- Detailed sustainable design	- Review project team - Prepare detailed design - Identify material - Update deliverables - Liaison with authority - Financial arrangement	- Integration of sustainable elements into design - Conduct BREEAM - Prepare Environmental statement - Compliance with legislation
PHASE SIX - Coordinated Design, Procurement & Full Financial Authority *' Are major design elements fixed?'*	- Gain full approval to proceed	- Sustainable design preparation	- Submission to authority - Liaison for design approval - Liaison for financial approval - Review supply chain	- Integration of sustainable elements into design - Prepare environmental statement - Update sustainability plans
PHASE SEVEN - Production Information *' Is the detail 'right' for construction?'*	- Produce detailed production information	- Complete information to proceed work in sustainable manner	- Gather information - Finalise project plans - Consider work packages - Tendering process	- Select and get information from tenderers with respect to sustainability issues
PHASE EIGHT - Construction *' Are we ready to hand-over the facility?'*	- Construct & complete project successfully	- Construct in sustainable manner	- Work commencement - Site mana99gement - Avoid changes - Appointment of suppliers / sub-contractors - Monitor work progress - Monitor cost - Coordination & communication - Public relations - Testing & commissioning	- Control pollution & prevent disturbances to local community - Using sustainable materials - Using sustainable construction methods

			- Hand-over preparation	
PHASES	**GOAL(S)** **PHASE**	**SUSTAINABILITY**	**PHASE ACTIVITIES**	**SUSTAINABILITY CONSIDERATIONS**
PHASE NINE - Operation & Maintenance *' What can we learn?'*	- Compile lessons learnt from project - Success in operations	- Compile lessons for future sustainable projects - Achieving sustainability benefits	- Information storage - Feedback - Upgrade relevant documents - Evaluate project success - Defect liability period	- Provide information storage facility - Evaluate sustainability achievement - Introduce feedback mechanism

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