Managing Sustainability Knowledge for a Sustainable Built Environment

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Abstract

There has been growing awareness of the importance of sustainability in the built environment as it can improve the quality of life. Sustainable construction, which is the application of sustainable development practices to construction, can have a big impact on the quest for a sustainable built environment. Efforts investigating ways of achieving sustainable construction targets recognised the importance of capturing and managing the knowledge required to improve sustainability in construction. This is being investigated within the C-SanD Project (Creating, Sustaining, And Disseminating Knowledge For Sustainable Construction: Tools, Methods And Architectures), which is being conducted in the UK by Loughborough University in collaboration with the London School of Economics, Salford University and a number of industry partners. The aim of the project is to develop, test, and implement software tools which enable the capture and retrieval of relevant knowledge, and to embed these tools in working methods that enable the creation of new knowledge particularly in the area of sustainable construction.

This paper presents project findings to date and discusses the issues identified during the field work conducted with practitioners from the industry. It highlights that little has been done to create and retain knowledge on sustainable construction and the need for a structured framework to consider sustainability issues within the whole construction process. The paper then presents a 'sustainability management activity zone' to support the implementation of sustainable construction practices integrated within a generic design and construction process map (Process Protocol). It concludes that there is much yet to be done in order to better manage sustainable construction knowledge within the industry. This is being addressed in the next stages of the C-SanD Project.

Keywords: Sustainable Construction, Knowledge Management.

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 Janeiro (http://users.whsmithnet.co.uk/ispalin/a21/); the Kyoto protocol for reduction in greenhouse gas emissions (http://unfccc.int/resource/convkp.html), the 'World Summit' in Johannesburg in 2002 (http://www.johannesburgsummit.org/), 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). On the other hand, a great reform is occurring around the world, which is based on information and knowledge and led by developments in computing and communications technology. According to Drucker (1993), the whole world has entered in a society which is based on knowledge and information. The society's basic economic resource is 'knowledge' and leaders of the society are 'knowledge workers'. This has led to a need to improve the management of knowledge within an organisation in all industrial sectors including the construction industry. Managing knowledge is particularly critical to the construction industry due to the unique characteristics of its projects such as having multi-disciplinary teams on construction projects; the temporary nature of a team and collocated members; heavy reliance on experienced staff; the one-off nature of construction projects; very tight construction schedules; very limited available finance for the whole design and construction of a facility; and last but not the least is the challenge to make construction activities more sustainable.

This paper gives an overview of sustainable construction, followed by an introduction to the C-SanD Project, presents initial project findings, and discusses the Knowledge Management (KM) issues identified by UK construction organisations during the case studies undertaken within the 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).

SUSTAINABLE CONSTRUCTION

Sustainable construction can be defined as "…The creation and responsible management of a healthy built environment based on resource efficient and ecological principles" (Langston and Ding, 2001). 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.

Miyatake (1996) presented six main principles for sustainable construction:

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.

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 Janeiro 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; DETR Report, 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 University, London School of Economics and University of Salford to look into the above issues with the help of leading construction client, contracting and consulting organizations.

THE C-SanD PROJECT

Background

To attain the goals of sustainable construction requires that the industry intensifies 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 latter point 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 for the C-SanD 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, i.e. Knowledge Management (KM).

Despite the interest and the effort put into KM 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 (Venters et. al., 2002). 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; and
- 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 desirable, 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 C-SanD 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/).

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.

Methodology

The research 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 uses 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 Object Oriented (Unified Modelling Language) modelling for technical components. For the social and organisational aspects, 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 Object Oriented (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.

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 (or scenarios) 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 in nine clusters being created, 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 example of one of these CATWOEs is shown in Figure 1, which was developed from the interview analysis as mentioned above. The next step is to transfer these CATWOEs into UML for the start of the primary modelling of the project.

Knowledge Management Issues

This section presents the knowledge management (KM) issues identified by the industrial partners of the C-SanD Project during the interviews. One of the major concerns was the KM challenges faced during the construction process itself. This includes the process of integrating the experts on a particular project; aligning different professionals to meet different constraints during the whole construction process; management of the supply chain during the construction process; changes done to the design of a facility by contractors on construction sites; waste management on the construction site; and poor English of many operatives on the site.

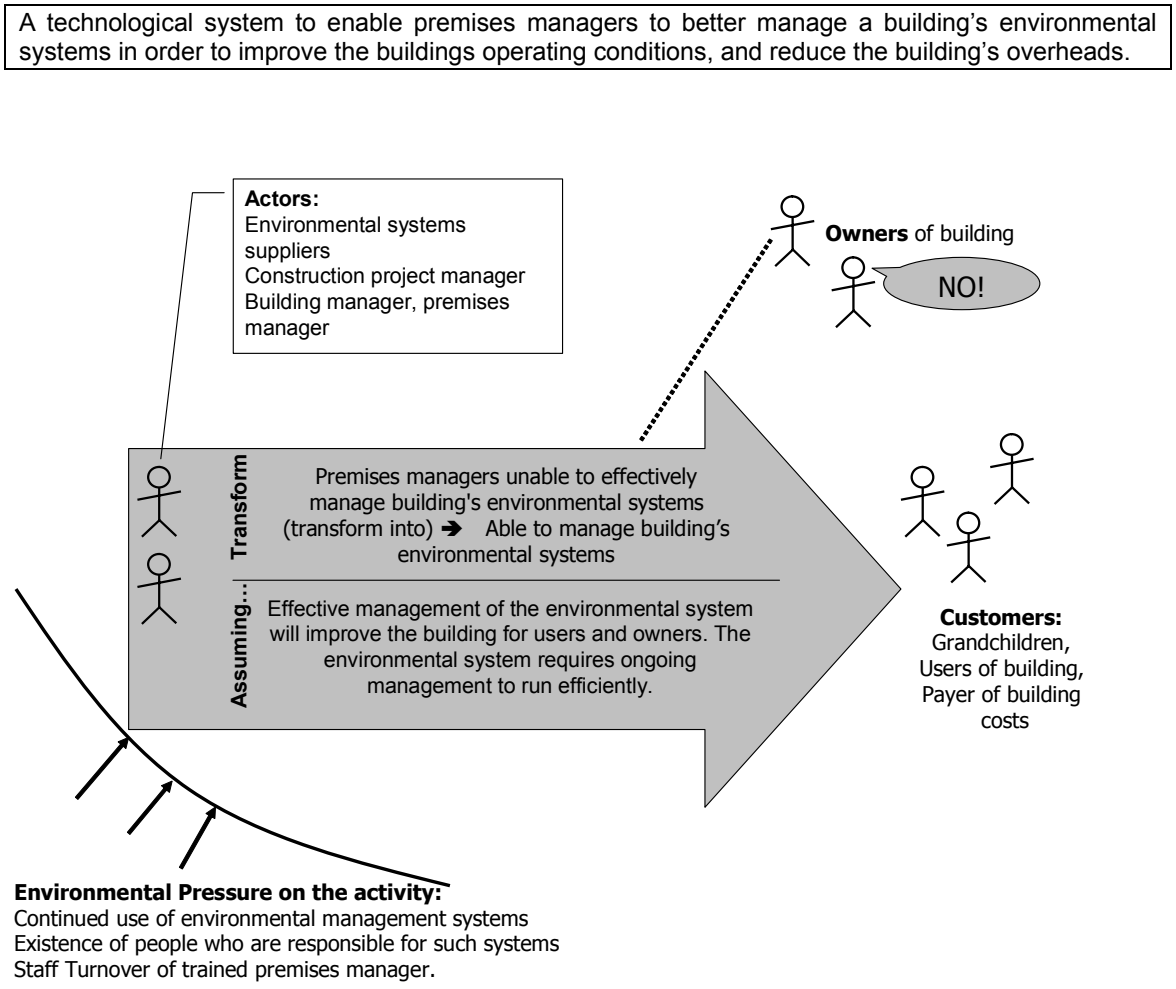

Figure 1: Example of a CATWOE

Some specific KM issues were also identified. These include the problems faced when people join construction companies; when a company acquires a new firm; when people leave a company; at the time of down sizing in a company; etc. Other issues were organisational culture included different groups/disciplines in one company working independently; people working apart rather than working as a team; less informal/casual contact between people working on the same project; problems faced

during staff turnover; variable quality of commitment of staff development and budgets; post-training commitment of staff; variable understanding and use of technology for knowledge dissemination; locating and developing skilled staff and experts; the matter of knowledge sharing vs. knowledge selling within a company, with project partners, and with other companies; and problems in knowledge sharing within large companies with a number of regional and overseas offices.

As far as small and medium size enterprises (SMEs) are concerned, it was noticed that they were knowledge users rather than knowledge producers. These firms work with small firms and are dependent on individuals developing their own knowledge during the design and construction processes. There is also a need for these firms to develop local networks to share knowledge. One of the major problems with SMEs is that they cannot maintain any sophisticated systems on their own, therefore they need web based access to external systems.

The interviews also revealed the problems related to the feedback and learning from past and ongoing projects. These problems included time limits to conduct project review; designers involvement ends before a facility comes into use; no formal learning for future projects, no formal feedback loops, no formal methods to capture best practices of the design and construction of a facility; designers' lack of knowledge on the performance of their designs when built; whether innovation in design work during the maintenance period of a facility; etc. It was also realised that there is a lot to be done in order to create, capture, store, manage, share, and disseminate knowledge specifically related to sustainable construction. In this respect the role of universities and R & D departments within firms was also highlighted as a way of improving these processes.

Most of the interviewees commented that information and communication technologies are the solutions to all the above mentioned KM problems. Large firms have already made heavy investments in intranets providing all project information and skills maps on desktops. But questions on this issue were: firstly, are these heavy investments used as intended? Secondly, are they really KM tools or only information management tools? And lastly, how effective are they for knowledge sharing especially for sustainable construction. These were some of the questions to be addressed by the C-SanD project team to fulfil the aim of the project, which involves development, testing, and implementation of software tools that would allow capture and retrieval of relevant knowledge, and enable the creation of new knowledge particularly in the area of sustainable construction (Khalfan et. al., 2002).

Sustainability Issues

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 identified 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. The analysis of the interviews revealed that different sustainability objectives were in conflict with each other. For example sustainability sometimes required costly innovation that conflicts with limited budgets, and hence limited client's motivation towards sustainable construction. Other issues highlighted during the interviews included:

- Waste reduction on construction sites which can be achieved through off-site construction;
- Management of sustainability knowledge (i.e. its creation, transfer, use, storage, etc.); and
- Weakness of Whole Life Cost (WLC) models (that could demonstrate long term benefits of sustainability) which results in giving priority to capital cost over operational cost.

There were also a few requirements identified by the interviewees needed to promote sustainable construction. These include the introduction of sustainability into the design 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 demonstrates sustainability impacts of day to day work on a construction projects; and using sustainability criteria for the selection of sub-contractors, materials, etc.

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 from the Government in the form of regulations and legislations, which would drive the industry towards sustainability. Another driver for 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, thereby 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 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 was to integrate sustainability within the whole life cycle of a building from design to construction and operation. The common question which arose from 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 a bolt-on extra. However, how it could be built-in was another question raised. To respond to this the project team decided to map sustainability issues on a generic project process map, the Process Protocol (see next section), to identify actions to be undertaken at different stages of the building life cycle.

SUSTAINABILITY MANAGEMENT ACTIVITY ZONE (SMAZ)

Tasks to improve a project's sustainability credentials were developed for the whole construction process at the project level and were integrated with the Process Protocol as mentioned above. The overall aim is to bring awareness of sustainability within the construction process and its practice at a specific project level. The main purpose of developing SMAZ is to make sustainability one of the management areas within Process Protocol, which would then drive all construction projects towards sustainable construction practices.

The Need

Although indicators have been previously identified, checklists have been prepared, and assessments have been carried out in order to check sustainability, there is a need for a structured, phase by phase activity map for the whole construction process from inception to the maintenance period, which would guide the industry to use such indicators and checklists in a more effective and efficient manner towards achieving sustainability goals. This need was identified as very important in the first round of interviews; the need for sustainability activities to be identified and built-in to different stages of the construction process; and the incorporation of these issues and activities into the planning and management of construction projects.

This need was also identified as an important aspect in improving sustainability by the engineers working on the project called 'The Engineer of the 21st Century' Inquiry, facilitated by The Forum for the Future in the UK. It was identified that there is need to embed the sustainability issues into all stages of construction process. Furthermore, it has appeared as one out of four change challenges in the recent report 'Change Challenges for Sustainability' by the Forum (Bennett & Crudgington, 2003; http://www.forumforthefuture.org.uk/uploadstore/Change%20Challenges%20for%20Sustainability.pdf).

The Process Protocol

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 was mapped into eight sub-processes (Activity Zones); Development, Project, Resource, Design, Production, Facilities, Health & Safety, Statutory and Legal, and Process Management; four broad stages, as in Pre-Project, Pre-Construction, Construction and Post-Construction; and ten phases. Some of the potential advantages of adopting the Process protocol as the industry standard are (Lee et al., 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.

The above mentioned advantages were the main driver for developing SMAZ as part of the Process Protocol.

Development of SMAZ

SMAZ was developed first in the form of a table (Khalfan et. al., 2003) and then further refined into an activity zone within the Process Protocol. The final version of SMAZ's first and second level of activities are the outcome of the following: a literature review; analysis of C-SanD Project's first and second round of interviews; participation in live project meetings of industrial partners; review of available sustainability checklists; indicators and assessment tools; in-house workshops with the C-SanD project team at Loughborough University; and validation with 20 construction related organisations.

The in-house workshops were one of the milestones in the development of the SMAZ. Once developed, it was validated within the construction industry to check its relevance, practicality, and use. Organisations such as local councils, consultants, contractors, etc. took part in the validation process. The validation was done in two stages: the first stage involved half of the organisations and resulted in an interim version of SMAZ; the second stage then involved the other half for more refinements. The selection of organisations was random except from the project partners.

Characteristic of SMAZ

SMAZ was developed in a similar format to the other activities within the Process Protocol including first and second level activities. Each phase of the Process Protocol contains one or more activities within SMAZ. A description for the SMAZ was also produced, which defines the aim of the zone, deliverables, etc. The first level activities are generic with more specific tasks defined in the sub-activities (second level activities). See Figure 2 as an example of first level and second level activities for Phase 2 of SMAZ.

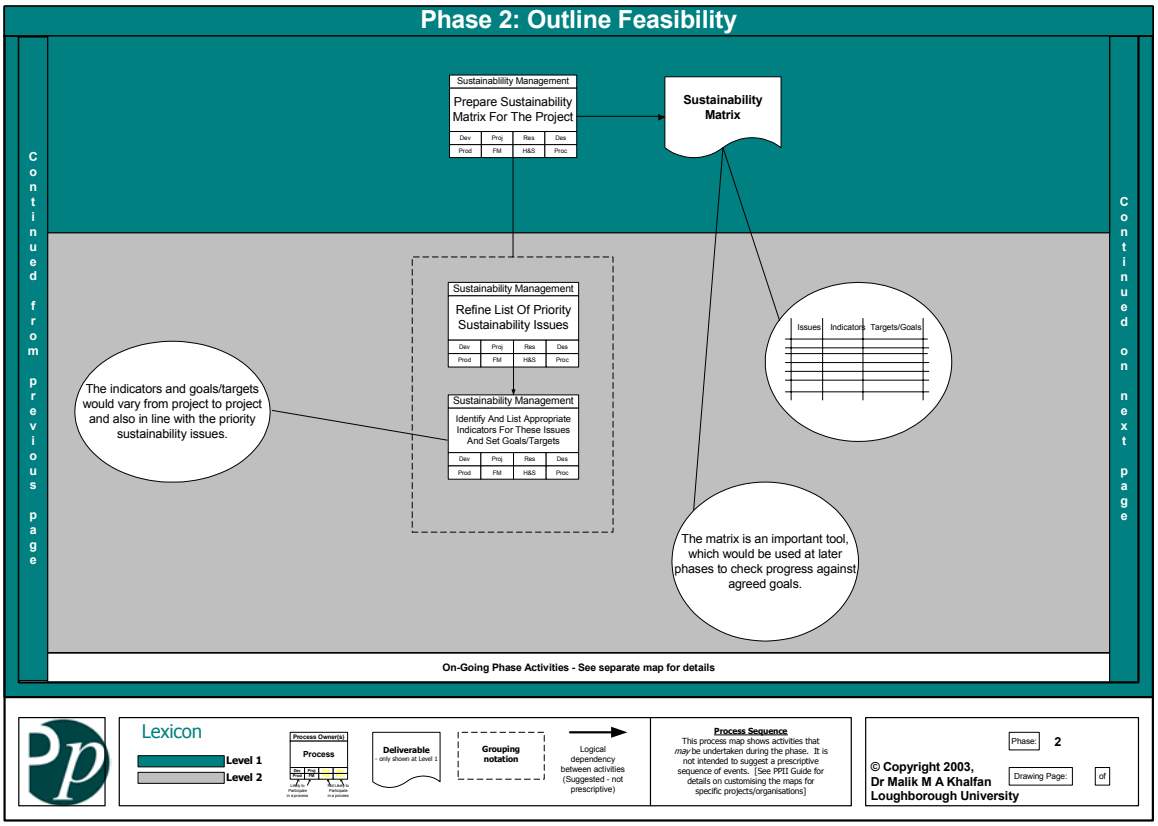

Figure 2: An example of first level and second level activities of SMAZ (Phase 2)

The availability of the SMAZ on the internet on the C-SanD project website (www.c-sand.org) will provide experts from industry and academia with the opportunity to try it fully or partly in different projects. The next version would contain supportive documents for each activity within SMAZ. One of such documents, a compilation of most of the sustainability issues within construction industry, has been prepared and will be available within the SMAZ online version.

The development of SMAZ is carried out in such a way that it can be used with or without the Process Protocol. Although it was prepared to be integrated with the Process Protocol, its activities have also been structured in-line with the RIBA Plan of Work used in the UK, and also with the more generic design and construction phases (which includes pre-project, design, construction, and post-construction phases). This attribute has made SMAZ a generic tool which can be used not only within the UK but also outside the UK, with the possibility of being adopted in any design and construction process framework.

Using SMAZ

The following are considerations which should be kept in mind while using the SMAZ:

- The SMAZ is specifically developed for use at construction project level, but some of its activities could be translated for use at organisation level.
- The project team needs to be practical in their vision while identifying the issues, indicators and targets in the early phases.
- The targets set during the initial phases should be SMART Targets, i.e. Specific, Measurable, Achievable, Realistic, Time-bound.
- SMAZ can also be used for a demolition or refurbishment projects.
- The mission statement, sustainability matrix, checklist, strategy, etc. could be part of a sustainability plan, which could be documented into the project brief first and then could form part of overall project development plan.
- SMAZ is very simple to use but needs one person (manager/champion/consultant) to oversee its implementation throughout the whole project.
- Using SMAZ is made easy, for example, Phase four of the Process Protocol framework, under pre-construction, covers Outline Conceptual Design, the different activities 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 by using the Matrix developed in phase 2. These activities are also integrated with other sub-activities carried out in other activity zones. For example the list of all the suppliers should be prepared and reviewed with respect to material's quality, re-cycleability, etc. Cost plans and procurement plans should be prepared and reviewed considering sustainable construction criteria as identified. The final alternative can then be decided upon, based on which alternative best meets the project's sustainability objectives.

SUMMARY, CONCLUSIONS, AND FURTHER WORK

This paper presented a brief overview into knowledge management (KM), 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. The later part of the paper discussed the KM issues identified within the construction industry during the case studies undertaken in the project. A need to incorporate sustainability within the whole construction process was also identified and resulted in the incorporation of these issues within the Process Protocol, which is a generic design and construction process map. The result was a Sustainability Management Activity Zone (SMAZ), which was developed in such a way that it considers the whole supply chain within the construction industry to achieve a more sustainable project. An important aspect of SMAZ is that it ensures that those sustainability issues which are sometimes ignored or overlooked during the whole process of project development, are properly taken into account by the project development team. The checklist included would also be able to help the project team to identify sustainability considerations for a specific project at the outset, enable them to consider sustainability as part of project development process, and help them to set practical targets and goals.

Further work includes linking the supporting documents to SMAZ and the implementation of SMAZ to a live project within the industry to assess the full potential of the framework. This further work also

includes the development of a Readiness Assessment Tool for construction organisations to support SMAZ activities at the project level.

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