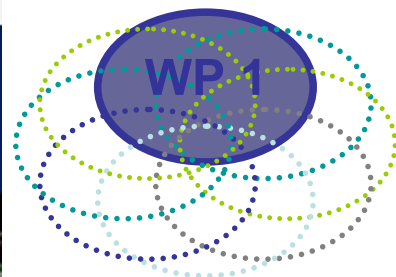


Knowledge Production, Sources &
Capabilities in the Construction Industry
Work Package 1- Final Report
February 2003



Knowledge Management for
Sustainable Construction Competitiveness 



www.knowledgemanagement.uk.net

Knowledge Production, Resources & Capabilities in the Construction Industry

Work Package 1- Final Report

February 2003

This project is supported by the Department of Trade and Industry (DTI) as part of the 'Knowledge Management for Sustainable Construction Competitiveness' Project (Partners in Innovation: CI 39/3/709).

Support is also gratefully received from the following industrial partners:

Association for Project Management (APM), Balfour Beatty Plc, Ballast Plc, Centre for Advanced Built Environment Research (CABER), Construction Best Practice Programme (CBPP), Construction Productivity Network (CPN), EC Harris, HBG Construction, IBM UK Ltd, IT Construction Best Practice (ITCBP), Kier Construction, Movement for Innovation (M4I), National House Building Council (NHBC), Ove Arup.

We are also grateful to the following companies who contributed to this work-package by making staff available for interviews:

Amec, Balfour Kilpatrick, Ballast Construction, Ballast plc., Cyrotech, Doig & Smith, EC Harris, ERJV, HBG Construction Ltd., Keppie Architects, Kier Scotland, Shepherd Construction, Taylor Woodrow Construction Ltd., Waterman Partnership

Research Team:

Prof Charles Egbu	Esra Kurul	Glasgow Caledonian University
Prof Paul Quintas	Dr Vicky Hutchinson	Open University Business School
Prof Chimay Anumba	Kirti Ruikar	Loughborough University

Project Officer (on behalf of the DTI):

Dr Anna McCrea- Davis Langdon Consultancy

1. INTRODUCTION	1
2. EXECUTIVE SUMMARY.....	2
3. KNOWLEDGE MANAGEMENT & KNOWLEDGE PRODUCTION:	
AN OVERVIEW	3
3. 1. APPROACHES TO KNOWLEDGE PRODUCTION	6
4. METHODOLOGY	9
5. ANALYSIS	11
5. 1. TRIGGERS OF KNOWLEDGE PRODUCTION.....	11
5. 2. KNOWLEDGE SOURCES & CAPABILITIES IN THE CONSTRUCTION	
INDUSTRY	14
5. 3. KNOWLEDGE PRODUCTION PROCESS	18
5. 4. KNOWLEDGE PRODUCTION FROM INDUSTRY, ORGANISATION AND	
PROJECT PERSPECTIVES	19
5.4.1. THE INFLUENCE OF THE CHARACTERISTICS OF	
THE CONSTRUCTION INDUSTRY ON KNOWLEDGE PRODUCTION	19
5.4.2. THE INFLUENCE OF ORGANISATIONAL CULTURE ON	
KNOWLEDGE PRODUCTION	21
5.4.3. THE INFLUENCE OF THE CHARACTERISTICS OF INDIVIDUAL PROJECTS	
ON KNOWLEDGE PRODUCTION	23
6. CONCLUSIONS & RECOMMENDATIONS.....	25
7. REFERENCES.....	28
8. APPENDIX 1	32

List of Tables

Table 1. A breakdown of interviews.....	10
Table 2. Triggers of knowledge production	12
Table 3. Knowledge production triggers at disaggregate level.....	14
Table 4. Knowledge Sources	15
Table 5. Knowledge Sources which are found to be 'most useful'	17
Table 6. Project Characteristics which promote/inhibit knowledge production...	24

List of Figures

Figure 1. The three elements of the knowledge-creating process.....	6
Figure 2. Dimensions of a knowledge production environment.....	8
Figure 3. Ten most frequently cited knowledge production triggers	13
Figure 4. Knowledge Sources- in descending order of use.....	16
Figure 5. Construction Industry Characteristics which promote knowledge production	20
Figure 6. Construction Industry Characteristics which inhibit knowledge production	21
Figure 7. Aspects of Organisational Culture which promote knowledge production	22
Figure 8. Aspects of Organisational Culture which inhibit knowledge production	23

1. Introduction

This final report is one of the deliverables of a 2-year comprehensive study, which commenced in July 2002 and which is funded by the Department of Trade and Industry (DTI) as part of the Partners in Innovation Programme (PII). The study is entitled “*Knowledge Management (KM) for Sustainable Construction Competitiveness*” (Partners in Innovation: CI 39/3/709). The primary aims of study are to investigate the challenges associated with the management of knowledge resources and capabilities for construction. Also, to establish how effective the strategies for managing these resources and capabilities are at contributing to project success and sustained organisational competitiveness. The targeted objectives for addressing the above aims are:

1. To identify the specific features of knowledge production in the construction industry – i.e. identifying what are the key types of knowledge resources and capabilities relevant to the sector (e.g. theoretical construction, engineering and design knowledge, plus experiential knowledge, etc.), the triggers of knowledge production and the challenges associated with producing ‘new’ knowledge.
2. To investigate and document the main challenges (including economic, social, technological, environmental) associated with the implementation, exploitation and embedding of KM practices within construction organisations of varying sizes and specialisms.
3. To examine and document the different approaches (including processes and technologies) used for knowledge production, absorption (across boundaries), capture & retrieval, transfer, sharing, exploitation and for measuring and comparing KM performance; together with their relative effectiveness as knowledge management tools. It will also investigate and document the vagaries of factors that lead to successful KM practices in different sizes of organisations and in organisations that are at different levels of KM implementation.
4. To explore knowledge management practices in other sectors (e.g. manufacturing, finance, IT, retail) with the view of documenting good and best practices for the benefit of the construction industry.
5. To examine the backgrounds and on-going training and skills of knowledge management specialists. Map out their career paths, examine and document the impact of this new role on the future of the construction industry.
6. Produce a study report, which could be used as a policy document and would influence the direction of both government and those concerned with improving the industry’s performance.
7. Produce a training material on KM and disseminate the outputs of the study on KM widely in the industry.

The planned outputs of the study include reports for construction organisations and policy makers, fact sheets, training materials for workshops, seminars and CPD purposes; journal and conference articles. The dedicated web-site for detailed information on the study and for disseminating some of the study outputs is: <http://www.knowledgemanagement.uk.net>

2. Executive Summary

This final report attempts to address some aspects of the first project objective (see page 1). It thus concentrates on the production of knowledge in the construction industry. Knowledge production is a sub-process of the knowledge management process. Knowledge management process also involves knowledge sharing (across boundaries), capture/storage, synthesis and application.

The objectives of WP1 are:

- to examine and identify the specific characteristics of knowledge production in the construction industry;
- to document the key types of knowledge resources and capabilities relevant to the sector.

The following are the main conclusions from this aspect of the study.

The main triggers of knowledge production are:

- Problem solving;
- Innovation;
- Managing change.

The main sources upon which individuals draw to produce new knowledge are:

- other individuals,
- the project team/supply chain,
- organisational routines,
- repositories,
- communities of practice; and
- knowledge gate-keepers.

Knowledge production is a complex process. It can occur through a number of ways. Organisational capabilities play a vital role in this regard. In the main, construction organisations produce knowledge through transforming existing knowledge, and reflective practice.

3. Knowledge Management & Knowledge Production: an overview

'Knowledge' and 'knowledge management' (KM) mean different things to different people and different organisations. The differences in meaning stem from the individual's/organisation's perception and awareness of their knowledge-base, and their approaches to exploiting and enhancing it. It is therefore necessary to provide working definitions of these terms before reviewing the developments in KM in the past decade.

For the purposes of this study, knowledge is defined as "A fluid mix of framed experience, values, contextual information, and expert insight" (Davenport and Prusak, 1998). One of the most comprehensive definitions of knowledge management comes from a Xerox manager, who defined KM as the '[creation of] a thriving work and learning environment that fosters the continuous creation, aggregation, use and re-use of both organizational and personal knowledge in the pursuit of new business or organizational value' (Cross, 1998:11).

KNOWLEDGE
SOME DEFINITIONS...
 'Justified true belief' (Plato)
 'The whole set of insights, experiences and procedures which are considered correct and true and which, therefore, guide the thoughts, behaviours and communication of people' (Van der Spek, 1997)
 'Knowledge consists of truths and beliefs, perspectives and concepts, judgements and expectations, methodologies and know-how' (Wiig, 1993)

KNOWLEDGE MANAGEMENT
SOME DEFINITIONS...
 'Powerful environmental forces, which are reshaping the world of the manager of the 21st century, call for a fundamental shift in organisation process and human resource strategy. This is knowledge management' Taylor et al. in (McAdam, 1999a)
 'Knowledge management is the activity which is concerned with strategy and tactics to manage human centered assets' (Brooking, A. 1997)

The last decade has seen an increased interest in knowledge management by organisations in a variety of sectors, and by academia (Despres and Cheuvel, 1999; Grant, 2000; Ives, *et al.*, 1998; McAdam and McCreedy, 1999a; von Krogh and Grand, 2000). There is strong and compelling evidence that the effective management of an organisation's knowledge sources and capabilities is vital for improving organisational competitiveness. (Cross, *et al.*, 2001; Egbu and Botherill, 2001; Kamara, *et al.*, 2002; Quintas, 2002).

As the interest in KM grew, different schools of thought emerged¹. These schools can be categorised into three broad types: technocratic, economic and behavioural (Earl, 2001). The management practices, techniques and technologies adopted by the individual schools vary. The technocratic school of thought focuses on information management or management technologies which are thought to assist the employees in improving their business performance. The economic school of thought regard knowledge as an intellectual capital/asset to be exploited. Finally, the behavioural school endeavours to create a business culture which stimulates knowledge production, sharing and (re)use.

It is commonly argued that the main driver behind the increased interest in KM is the recognition that knowledge is an asset, just like the physical assets of an organisation (Ives, *et al.*, 1998; Wiig, 2000). Thus, the initial approaches to KM focussed on managing and making more efficient use of an organisations' 'intellectual capital'. However, the 'current conceptual struggle' appears to be in developing KM initiatives which take account of both the existing knowledge *assets* and, the *processes* and *capabilities* of an organisation.

It is important for KM initiatives to aim to tap into the existing knowledge in an organisation by systemising it, thus 'capturing' the existing knowledge base. Similarly, they have to facilitate the knowledge management processes which include production of new knowledge². Production of new knowledge is 'a series of transformations, by which standard resources, which are available in open markets [or contained within the organisations], are used and combined within the organisational context of in order to produce [competences and] capabilities' (Ciborra and Andreu., 2001:74). Competences and capabilities (unlike resources) are unique to each organisation, and so are the sources of competitive advantage (Grant, 1991).

Bajaria (2000: 562) states that knowledge systematization and production must be handled 'simultaneously, not sequentially'. However, the majority of current KM practices seem to be biased towards managing the existing knowledge base and they

¹ Some authors term the schools of thought 'knowledge management models'. See Venters, 2002; Despres and Chauvel, 2000; Despres and Chauvel, 1999; McAdam and McCreedy, 1999a for a detailed overview of the KM models.

² Knowledge production and knowledge creation are considered to be synonymous for the purposes of this report.

employ information technology to do so (Nonaka, *et al.*, 2000:89). This suggests that there is a gap in the deployment of KM that is potentially problematic.

As a result of the preoccupation with systematising the existing knowledge, the sub-process of knowledge production has been relatively under-researched (Krogh *et al.*, 2000). The limited number of studies on knowledge production in 'learning organisations' have yielded highly abstract frameworks (Salisbury, 2001). These frameworks are not suitable for addressing how employees produce new knowledge or for identifying ways of stimulating the production process. This is so because they are based on how individuals learn through their cognitive systems, and thus they cannot resolve the dilemma between the individual as entities *learning* on behalf of the organisation and the organisation *memorising* what the individuals have *learnt* (Hedberg, 2000).

Furthermore, the above perspective on organisational learning and knowledge production is based on Systems Thinking, which presupposes 'designing and installing systems' as the solution to the KM problem (Stacey, 2001:26). This perspective is even more problematic in the construction industry, where 'even the management of [existing knowledge] is still an under-chartered territory' (Kululanga and McCaffer, 2001:346). Given both the problems the systematization approach causes and the low level of KM maturity in the construction industry, WP1 concentrates on the specific aspects of knowledge production in the industry. It also aims to document the key types of knowledge sources and capabilities within the industry.

3. 1. Approaches to Knowledge Production

There are three distinct streams of thought in knowledge production. The first, which Stacey (2001) terms ‘mainstream systems thinking’, considers knowledge categorically and argues that new knowledge is produced through the transformation of existing knowledge from one form into another (Boisot, 1998; Hedlund, 1994; Nonaka and Nishiguchi, 2001)³.

For example Nonaka and Takeuchi (1995) define knowledge production as a continuous, social process, ‘which is a never-ending spiral of tacit and explicit knowledge through knowledge conversion, **S**ocialization, **E**xternalisation, **C**ombination and **I**nternalization [SECI]’ (Sverlinger, 2000). This transformation process is inextricably linked to ‘the shared context of knowledge creation (*ba*) and ‘knowledge assets (the inputs and outputs) and moderator of the knowledge-creating process’ (Nonaka *et al.*, 2000: 8). Figure 1 depicts the three elements of the model and reveals the intricacy of the knowledge production process.

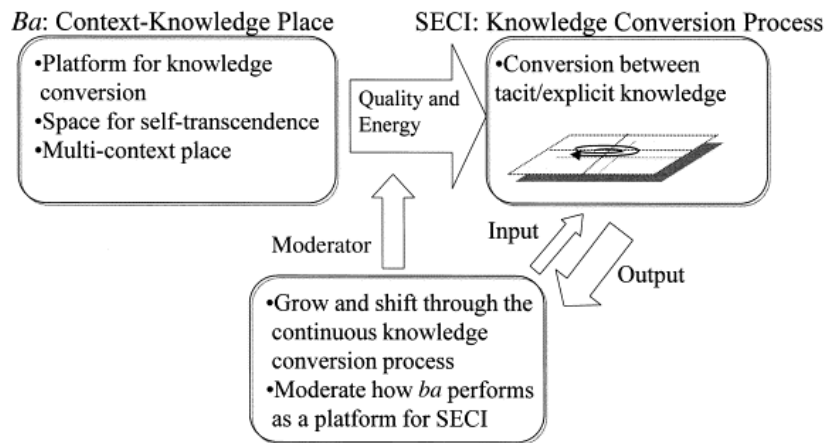


Figure 1. The three elements of the knowledge-creating process

Source: Nonaka *et al.* (2000).

The ‘social constructionist approach’, which is the second stream of thought in knowledge production, emphasises the relationship between action, understanding and

³ See Despres and Chauvel, 2000; Despres and Chauvel, 1999; McAdam and McCreddy, 1999a; McAdam and McCreddy, 1999b for a critical review of these models.

communication as the key to knowledge production and the dissemination of existing knowledge (Venters, 2002). This stream of thought often refers to the works of Argyris and Schön who concentrate on learning (Argyris and Schön, 1996; Argyris and Schön, 1978). They also emphasise that knowledge and its production are closely linked to the social and learning processes of the organisations (context). In these terms, the social constructionist models come close to the 'mainstream systems thinking' because they both emphasise the significance of context in producing knowledge.

Gibbons *et al.* (1994) adopt a similar perspective to knowledge production. They define two distinct modes of knowledge production: Mode 1 and Mode 2. Mode 1 is institutionalised knowledge (the type that forms the basis of university engineering courses). Mode 2 knowledge is created in practice. Knowledge production in Mode 1 (traditional mode of knowledge production) takes place in a disciplinary context. There is a clear distinction between theory and its application in this mode of knowledge production. 'Scientific' knowledge produced at the universities is an example of Mode 1 knowledge production. Mode 2 is considered to be an extension of Mode 1 knowledge production. It embraces the 'transdisciplinary social and economic contexts'. The context of knowledge production is less defined in Mode 2 than it is in Mode 1. Mode 2 knowledge is increasingly produced in the application context.

The third stream of thought takes up a 'complex responsive process' perspective (Stacey, 2001). 'From this perspective knowledge is meaning and it can only emerge in the communicative interaction between people. [Knowledge is] continuously reproduced and potentially transformed in action. Thus, the patterns of participation in the ongoing flow of communicative interaction lie at the core of knowledge production.' (ibid)

It can be argued that the 'complex responsive process' perspective can be more instrumental in understanding the knowledge production process in organisations than the 'mainstream systems thinking' because it facilitates the exploration of knowledge production at both the individual level and the organisational level. Thus, the complex knowledge management processes can be studied without being reduced to objective elements. In addition, the transformation of the tacit knowledge of the individual to the explicit knowledge of the organisation becomes more readily understandable. However, this perspective is rather difficult to operationalise within the context of this study and, more importantly, in terms of its outputs and recommendations to the industry. As a result, this report bases its conceptual framework on the 'mainstream thinking'.

Fundamental components of knowledge production, according to our conceptual framework, are given in Figure 2. These include the process of knowledge production, its triggers and the knowledge sources. All the components are contained in the context of knowledge production and they are analogous to Nonaka *et al.*'s (2000) elements of knowledge-creating process.

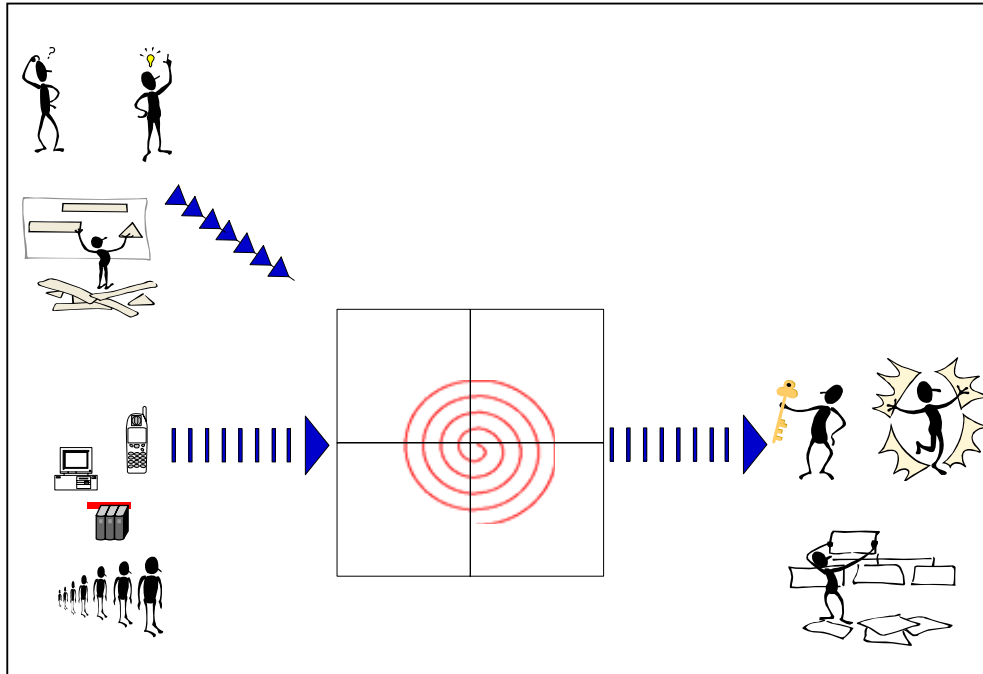


Figure 2. Dimensions of a knowledge production environment

The process of knowledge production is activated by the triggers which include the need to solve problems, the motive to innovate and the management of change. Quite frequently, existing knowledge is an input to the knowledge production process. Existing knowledge can be sourced from a number of sources which can be internal or external to the organisation. During the knowledge production process new knowledge is produced by moving around the quadrants of the knowledge spiral. New knowledge is produced at the end of the process. Outputs include solutions to problems, innovation and change. Knowledge production in the construction industry will be considered under these headings. Knowledge production is a complex process which can occur in a number of ways, e.g. formal research, reflective practice.

Need to solve
problems

Motive to innovate

4. Methodology

This section communicates our methodological approach to the research undertaken as part of this phase of the study. It thus briefly explains the data collection method and the analytical approach.

This phase of the study aims to *explore* knowledge production within the construction industry. The decision to conduct an *exploratory* study was mainly driven by the limited number of empirical studies both on knowledge management and on knowledge production in the construction industry. The nature of the problem under investigation, i.e. exploratory, dictated the adoption of a qualitative research strategy, as well as the choice of semi-structured interviews as the means of data collection.

Thirty-one semi-structured interviews were conducted with practitioners in the construction industry (See Appendix 1 for the topics covered during the interviews). The interviewees were spread across fourteen construction organisations. Six of these were large. Another six were medium and two were small.

It was our aim to cover the breadth of the practitioners from the consultants to the work-force on site. We approached our Industrial Partners for interviews and requested their advice on potential interviewees within their supply-chain⁴. Thus, our data-sample was drawn from successive contacts provided first by our Industrial Partners and then by our interviewees.

Table 1 shows the spread of interviews conducted across the different project roles. Ten, twelve and nine interviews were conducted with Senior Managers, Middle Managers and Site Employees respectively. Thus, our sample was distributed between the different hierarchical levels of the organisations. Even so, our data sample has certain limitations. These limitations mainly emanate from the lack of a comprehensive database from which we would have drawn our sample. In addition, the majority of our interviewees were at managerial positions.

⁴ Please refer to Page (i) for a list of the organisations which made staff available for the interviews.

	Role	Number of interviews per role	Number of interviews per level
SENIOR MANAGEMENT	Partner	1	10
	(Regional) Construction Director	2	
	Project Director	6	
	Director of Management	1	
MIDDLE MANAGEMENT	HR Manager	1	12
	Contract's Manager	2	
	Planner	1	
	Architect	1	
	Quality Manager	1	
	Planning Manager	1	
	Engineering Manager	1	
	Design Manager	1	
	QS	2	
	Project Manager	1	
SITE EMPLOYEES	Site Manager/ Engineer	8	9
	Foreman (Site Supervisor)	1	

Table 1. A breakdown of interviews

Content analysis was adopted as the analytical approach. The empirical data collected through the interviews was analysed under the issues which were identified to be central to understanding knowledge production within the construction industry.

5. Analysis

5. 1. *Triggers of knowledge production*

The construction industry's fundamental task is to deliver solutions to the clients' 'problems'. In addition, increasing competitiveness in recent years and the increased pace of change have brought about the need to be innovative and capable of adapting to changing circumstances quickly. In order to deliver better service to their clients and remain competitive, construction organisations should improve on past solutions, innovate and manage change. These can be achieved by producing new knowledge.

The analysis of interview data has shown that the triggers of knowledge production in the studied construction organisations are:

- Problem solving;
- Managing change; and
- Innovation.

At this juncture it is important to note that not all change management activities result in innovation. So, in this study, change management and innovation are considered separately. It is also worthy of note that the management of change can be associated with organisational change as well as changes which are made during project development and implementation.

Table 2 lists the triggers of knowledge production which were cited by the respondents during the interviews. The triggers are grouped under the three main categories noted above. The main triggers are presented in Table 2 under each category, in decreasing order by of frequency citation.

As can be seen from Table 2, the majority of the triggers are associated with problem-solving and change management. Perhaps this reflects the nature of project-based environments. In the course of addressing the very changing nature of the project environments, with the need to meet the clients' needs and address the issues of resources, and manage the complexities of project teams, new knowledge is created. Interestingly, 'dealing with new, innovative building materials, systems and services', which are associated with innovation, is the second most frequently cited trigger (see Figure 3). In addition, the majority of the triggers associated with innovation are among the top ten triggers. Thus, it can be concluded that innovation is considered to be a

driving force behind knowledge production in the construction industry, despite the emergence of a relatively small number of triggers which are directly associated with innovation in this study.

Problem-solving	Managing Change	Innovation
<ul style="list-style-type: none"> • Dealing with complex projects • Managing team member interfaces (e.g. consultant-contractor) • Addressing value engineering issues to deliver best value • Addressing clients' needs • Identifying the knowledge gap • Dealing with contextual differences • Finding measures to increase company competitiveness • Dealing with lack of (design) information • Addressing the need to improve the quality of product/service • Addressing the need to improve efficiency • Addressing the need to recruit skilled people & retain them • Dealing with challenging site logistics • Dealing and coping with incompetent consultants 	<ul style="list-style-type: none"> • Managing changes to the project • Managing organisational change • Addressing the need to comply with standards (Quality Assurance, Health and Safety, etc.) • Addressing the changes to statutory regulations, technical standards • Dealing with contractual arrangements new to the respondent • Being enabled to make design choices • 'Working with new sub-contractors' • Being assigned to a new role • Addressing the need to establish a data transformation system for the whole project team • Addressing the need to create a 'database' • Coping with Government initiatives (e.g. PFI, partnering) 	<ul style="list-style-type: none"> • Using new, innovative building materials, systems, services • Coping with the uniqueness of projects • Dealing with the need and willingness to be 'ahead of the game', 'move the market' • Addressing the pressures & need to innovate ('look at new ways of doing things')

Table 2. Triggers of knowledge production

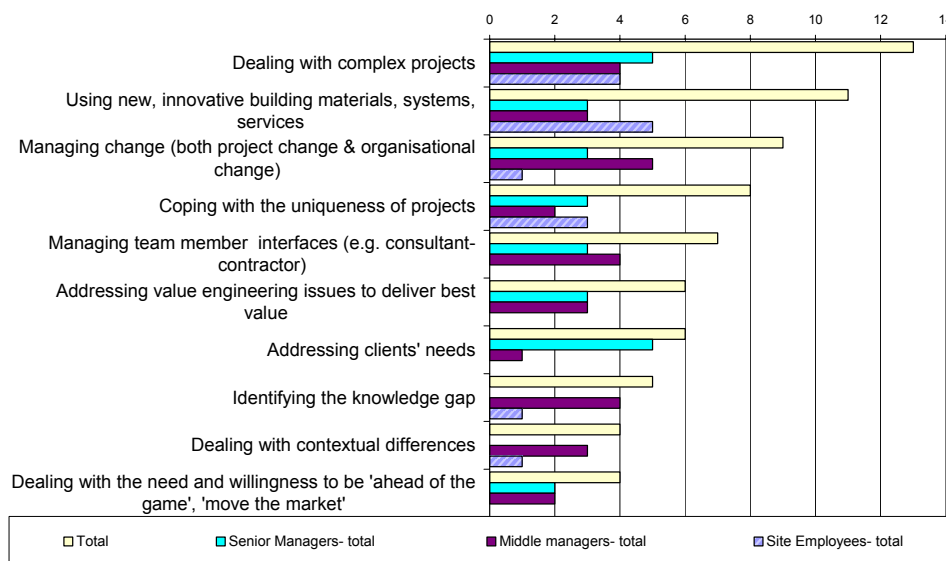


Figure 3. Ten most frequently cited knowledge production triggers

It is important to reflect on the issues associated with the triggers of knowledge production by considering the views of all managers and staff (at aggregate level) and at different levels of the organisational hierarchy (disaggregate levels) (see Table 1 (page 1) for the make-up of senior and middle managers and site employees). Figure 3 shows the ten most frequently cited k-triggers at the aggregate and disaggregate levels. It is evident from the figure that the top-five k-triggers are:

- Dealing with complex projects
- Using new, innovative building materials, systems, services
- Managing change (both project change & organisational change)
- Coping with the uniqueness of projects
- Managing team member interfaces (e.g. consultant-contractor).

These triggers received a very high frequency of citation at all levels of the organisational hierarchy. This suggests that there are certain triggers that are considered important for knowledge production at all levels, even with some variation in the relative frequency of citation at different levels.

In addition, the majority of the top-ten k-triggers are associated with problem-solving situations for all hierarchical levels. Thus, the industry

produces knowledge in order to solve problems. This can be interpreted as an indication of the responsive character of the industry.

A more detailed observation at the disaggregate level shows that there are triggers which are considered to be important at specific levels of the organisational hierarchy. For example, in this study, only Senior Managers noted that ‘addressing the need to innovate’ was a trigger for them to produce new knowledge. Again, only Middle Managers noted that ‘addressing the need to improve the quality of product/service’ was among the triggers which activated the knowledge production process for them. (See Table 3)

Triggers cited by Senior Managers only	Triggers cited by middle managers only
Addressing the need to innovate ('look at new ways of doing things') Addressing the need to establish a data transformation system for the whole project team Addressing the need to 'create' a supplier database Coping with government initiatives (e.g. PFI, Partnering)	Addressing the need to improve the quality of product/service Addressing the need to improve efficiency Dealing & coping with incompetent consultants Working with new sub-contractors

Table 3. Knowledge production triggers at disaggregate level

5. 2. Knowledge sources & capabilities in the Construction Industry

Knowledge sources, in this context, mean the ‘reservoirs of knowledge’ which a knowledge-worker has to fall back on in fulfilling his/her responsibilities. The effective utilisation of each source draws on the capabilities which are inherent in the organisation and its people. Here, the main sources of knowledge will be highlighted and discussed.

Table 4 shows the different types of knowledge sources documented in our study. In this report, the organisation is the context according to which knowledge sources are categorised. Thus, there are two main categories of knowledge sources, i.e. sources internal to the organisation and sources external to the organisation.

Knowledge Sources	
Internal to the organisation	External to the organisation
Other individuals (i.e. colleagues)	Other individuals (e.g. project team, supply-chain)
Team(s)	Communities of Practice (including project teams)
Routines	Other networks (e.g. seminars, exhibitions, conferences, etc.)
Competences	Repositories (e.g. regulatory documents, trade publications, web-sites)
Repositories (e.g. manuals, code of practice, reports/ organisational documents)	Knowledge gate-keepers (e.g. universities, professional institutions)

Table 4. Knowledge Sources

Table 4 indicates that there is a host of sources, where individuals and organisations can obtain relevant knowledge for project and organisational needs. Figure 4 shows the frequency at which individuals say they use the sources of knowledge in the kind of work they do. The sources are presented in decreasing order of the frequency of citation of use. The majority of the respondents noted that they rely on their colleagues as a knowledge source. 'Individuals in the project team and/or in the project supply-chain' follow respondents' colleagues as the second mostly-used knowledge source. The ranking of the Internet, in Figure 4, as the third most used source of knowledge, is indicative of the fact that the level of use and exploitation of IT as a source of knowledge is increasing, at least in the studied construction organisations.

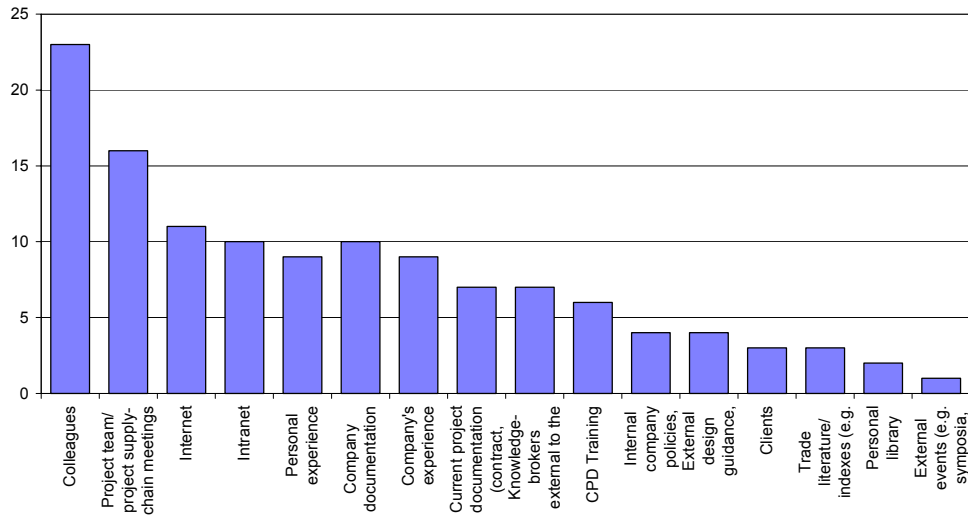


Figure 4. Knowledge Sources- in descending order of use

A closer observation of Figure 4 shows that the respondents make use of internal and external sources at similar degrees as appropriate. For example, ‘colleagues’ and ‘Intranet’ are internal sources. ‘Internet’ and ‘external events’ can be seen as external sources.

It is widely accepted that knowledge production is moderated by both the ‘content’ and the ‘context’ of the knowledge production process (Ferlie and Loch, 2001; Nonaka and Takeuchi, 1995; Nonaka and Toyama, 2000). Thus, the knowledge acquired from a source can become tacit, implicit or explicit depending on the context in which it is used.

The contextual nature of knowledge was also evident in the fact that the respondents found it difficult to identify which knowledge sources they found most useful. The most frequent reply to this question was that the usefulness of the sources depends on the circumstances which triggered the knowledge production process.

Context specificity of knowledge raises some important questions about the transfer of ‘best practice’. ‘Best practices’ do not necessarily have to be communicated through explicit knowledge. They can also be effectively conveyed through other means depending on the context. It therefore follows

that a balanced approach needs to be considered when reflecting on the media for communicating 'best practices'.

Despite the context specificity of knowledge, nine respondents could articulate more on the usefulness of different sources. They listed their colleagues, the project team/supply-chain meetings, Internet, knowledge-brokers external to the company and the Intranet as the most 'useful' sources of knowledge (see Table 5). This list is in descending order of 'usefulness' as perceived by the respondents. The type of knowledge they gathered from these sources could be tacit, implicit or explicit depending on the context in which knowledge was needed/used. Despite the contextual differences, the tacit knowledge obtained from colleagues and the project team/supply-chain meetings were regarded highly in 'enabling' the respondents to solve the problems they were faced with.

Colleagues
Project team/project supply chain meetings
Internet
Knowledge-brokers external to the company (e.g. professional institutions)
Intranet

Table 5. Knowledge Sources which are found to be 'most useful'

Individuals and organisations appear to be capable of producing the new knowledge they need by drawing upon the appropriate knowledge sources 'on their feet'. This capability aids them in accomplishing individual and organisational tasks. In the main, there appear to be no formal and systematic approach to the production of new knowledge. Formalising the knowledge production approaches, where appropriate and necessary, may increase the organisation's knowledge production capability. Organisations may be better served if more articulation of knowledge production capability is considered. This is more so where our study reveals that the production of new knowledge provides capabilities for dealing with innovation, problem solving and managing change.

5. 3. Knowledge Production Process

Some authors argue that ‘for an individual, knowledge [production] and learning are the same thing’ but organisational knowledge has to be produced consciously (DBA Associates and Gardiner & Theobald, 2003). Until recently, production of organisational knowledge has remained in the domain of ‘organisational learning’, which is argued to be fragmented, consisting of little constructs with little cross-fertilisation (Edmondson and Moingeon, 1996). The critique of organisational learning literature will not be made here as it falls out of the scope of this report. However, it will suffice to state that the organisational learning literature has been used to complement Nonaka’s SECI spiral and thus facilitate the exploration of the relationship between the different processes through which knowledge is produced, leading to competitive advantage.

Edmondson and Moingeon (1996) divide the knowledge production processes into two: *learning how* and *learning why*. *Learning how* is a process whereby existing skills and routines are transferred and improved. The improved skills and routines then enable the organisation to implement processes quickly with accuracy. *Learning why* focuses attention on discerning the underlying logic or causal factors in processes. At this juncture, it should be noted that *learning how* and *learning why* are not mutually exclusive, even though *learning how* is more closely associated with problem solving, while *learning why* is associated with change management and innovation in organisations.

Our research has shown that *learning how* is the dominant process of knowledge production within the construction industry. This follows that the industry’s main trigger of knowledge production is problem solving. As stated above, concentration on *learning how* does not exclude *learning why*. With the industry increasingly striving towards improvements in quality, health and safety; increased attention is paid to improving the processes. This necessitates firstly to understand why certain processes fail, and secondly to find ways of avoiding similar failures. It can therefore be stated that construction organisations produce knowledge through both *learning how* and *learning why*.

5. 4. Knowledge Production from Industry, Organisation and Project Perspectives

This section of the report will address knowledge production from three perspectives:

- The industry perspective;
- The organisational perspective; and
- The project perspective.

This section has two aims. Firstly, it concentrates on establishing how the characteristics of the industry, the organisational culture and the characteristics of individual projects influence knowledge production by promoting or inhibiting the creation of a knowledge production friendly environment. The influence of these factors on knowledge production is different from the influence of the triggers discussed above. K-triggers activate the knowledge production process. They thus have a direct influence. However, the characteristics of the industry, organisational culture and the characteristics of projects have an indirect influence on knowledge production through their influence on the business environment. Secondly, this section identifies the characteristics which promote and inhibit a knowledge production friendly environment.

5.4.1. The Influence of the Characteristics of the Construction Industry on Knowledge Production

It can be argued that the publication of Latham Report in 1994 was a milestone for change in the construction industry. Another milestone for change in the industry is the Egan Report (Egan, 1998). Improving the industry's productivity by addressing issues such as fragmentation, client dissatisfaction, low level of investment both in R&D and capital, and the lack of skills is the fundamental recommendation of the 'Rethinking Construction' report.

It is interesting to note that the respondents in this study referred to these issues in the context of knowledge production as well. In the main, the characteristics of the industry which were regarded to inhibit knowledge production are associated with the fundamental reasons behind its low level of

productivity. This corroborates the argument which asserts that knowledge production could assist improving organisational efficiency and productivity.

Figure 5 and Figure 6 represent, at a generic level, the characteristics of the construction industry which the interviewees considered to promote and to inhibit knowledge production respectively. The move towards change initiated by the Latham and Egan Reports ranked first among the driving forces behind knowledge production. Reluctance to change was most frequently cited among the barriers to producing new knowledge.

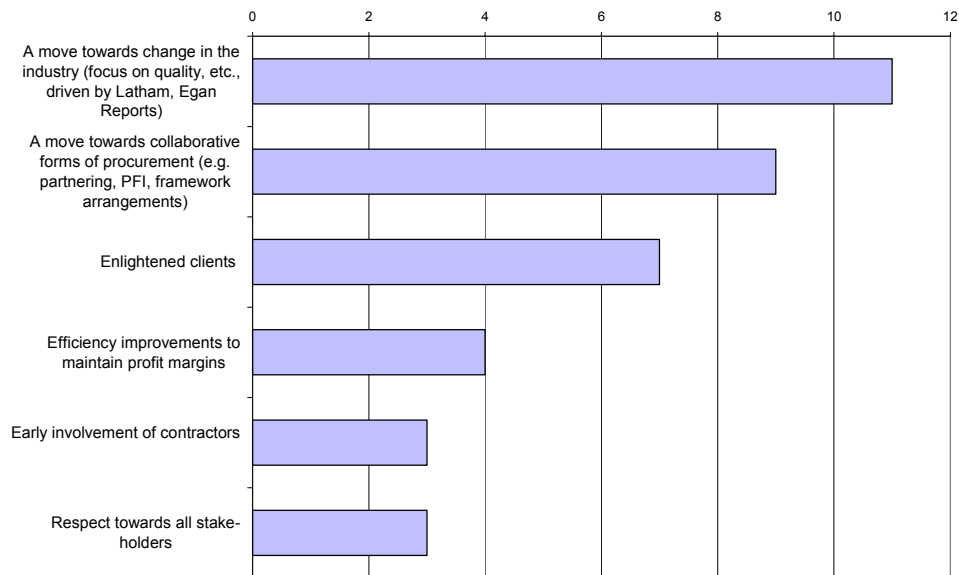


Figure 5. Construction Industry Characteristics which promote knowledge production

Partnering and framework agreements, which the Egan Report considers to be important in ‘tackling fragmentation’, support the production of knowledge. However, the fragmentation of the industry, its confrontational and litigious nature inhibit knowledge production.

In organisations which embrace change, initiatives associated with change become driving forces for knowledge production. On the contrary, the traditionally fragmented nature of the industry and the confrontation, litigation it leads to, becomes a barrier to knowledge production in organisations where (some) employees are reluctant to change routines.

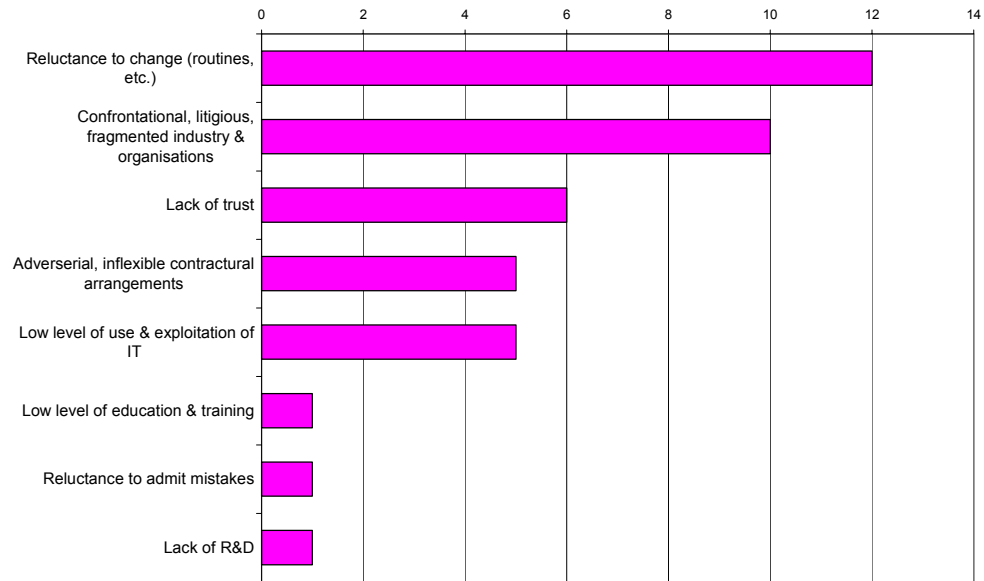


Figure 6. Construction Industry Characteristics which inhibit knowledge production

The Egan Report lists ‘low profit margin’ among the reasons of under-performance in the construction industry. On the other hand, the construction industry professionals consider ‘low profit margin’ as a motivation for increasing efficiency. The respondents in this aspect of our study stated that efficiency could be enhanced by ‘finding new ways of doing things’, and thus leading to the production of new knowledge. This finding is worthy of note as it points to the fact that in the industry’s quest to improve efficiency, knowledge production is regarded as vital.

5.4.2. The Influence of Organisational Culture on Knowledge Production

Knowledge is produced in a variety of ways in different organisations. The basic assumption is that organisational culture, which is the ‘way things are done’ in organisations, their values, and norms, influences knowledge production in many complex ways. For example, the values of an organisation play an important role in defining whether resources, specifically time, is available to reflect on past experience and produce new knowledge based on the past experience.

People, culture and organisational structures should all be considered in order to gain a comprehensive understanding of the influences of organisational culture on knowledge production. The inextricable link between

these issues was also reflected in the responses to the influences of organisational culture on knowledge production. The respondents referred to structure and people issues while they were articulating the impact of organisational culture on knowledge production.

Figure 7 and Figure 8 show aspects of organisational culture which the respondents, at a generic level, considered to promote and inhibit knowledge production respectively. The cultural variables are listed in descending order of citation in both figures.

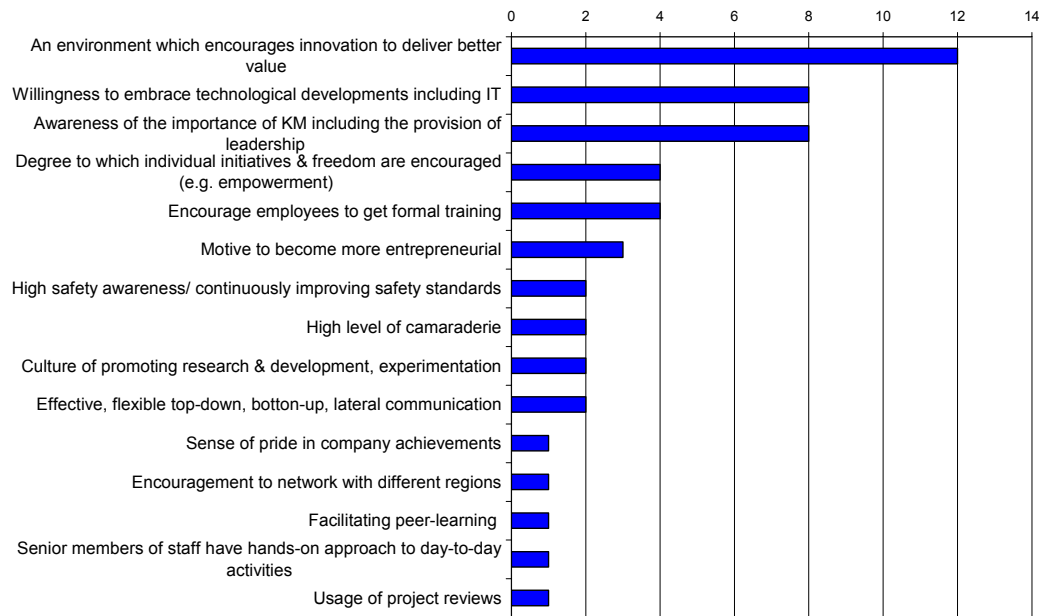


Figure 7. Aspects of Organisational Culture which promote knowledge production

The consideration of the aspects which promote knowledge production and those which inhibit it suggest that there are paradoxes between the values of the organisations studied and what organisation actually do (Schein, 1996). The most frequently cited cultural promoters and inhibitors of knowledge production support this argument. ‘An environment which encourages innovation to deliver better value’ is the most frequently cited promoter (Figure 7). However, ‘time pressure’, which does not make time available for reflection on the project experience, is the most frequently cited obstacle (Figure 8). If organisations are to deliver better value through innovation, then they need to be prepared to provide adequate time for their

employees to reflect and provide relevant knowledge needed for appropriate innovations.

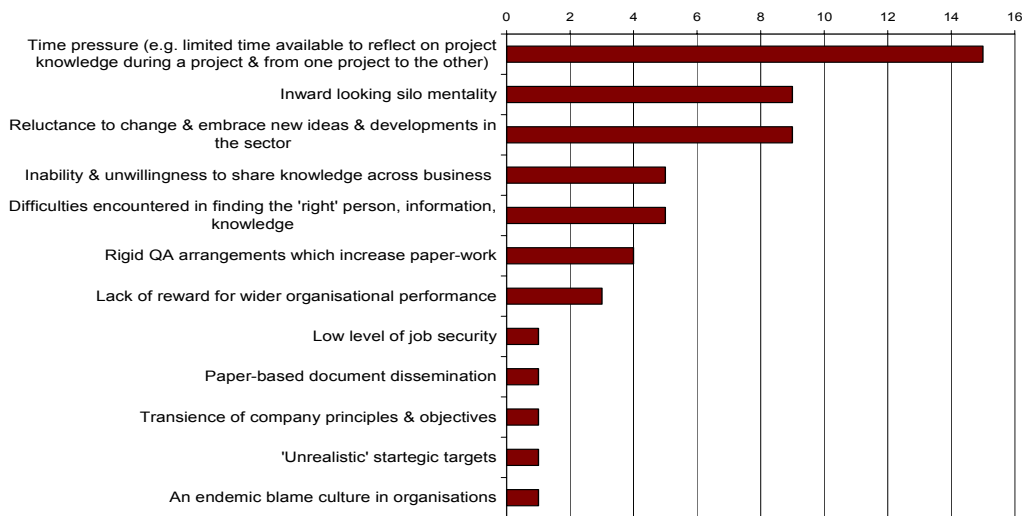


Figure 8. Aspects of Organisational Culture which inhibit knowledge production

The paradox that exist in the ‘way things are done’ and the ‘espoused values’ is also evident in the emergence of ‘inward looking silo mentality’ as the second-most cited obstacle to knowledge production (Figure 8). On the one hand, organisations aspire to capitalise on their existing project experience and encourage coordination between individual business units. On the other hand, they fall victim to the ‘silo mentality’.

5.4.3. The Influence of the Characteristics of Individual Projects on Knowledge Production

Table 6 presents the project characteristics which were cited as promoters and inhibitors to knowledge production. The table, with factors in descending order of frequency of citation, shows that team composition plays a significant role in knowledge production. The fundamental attribute of an effective team is its flexibility and responsiveness in responding to the emergent problems and opportunities. This is largely facilitated by the high level of expertise and ‘adequate knowledge-base’ within the team. The presence of trust among the team members assists knowledge production because team members are more willing to share knowledge if they trust one another. The respondents agreed that team stability, i.e. continuous

involvement of the same team members throughout the project life-cycle, was important in establishing trust between team members. Given the high member turnover within and across construction project teams, it can be concluded that the nature of the construction project environments *creates* obstacles to knowledge production by not using the same people throughout the project life-cycle.

Project Characteristics promoting knowledge production	Project Characteristics inhibiting knowledge production
Effective team composition & high level of expertise	Ineffective team composition & low level of expertise
Presence of trust between team members/ team stability	Scarce project resources (e.g. time, budget)
High levels of project complexity	Lack of trust between team members/ team instability
Need to address a problem / challenge by finding bespoke solutions	'Re-inventing the wheel' syndrome
Adequate project resources (time, budget, etc.)	-

Table 6. Project Characteristics which promote/inhibit knowledge production

It is therefore arguable that project complexity (e.g. increased number of subcontractors/suppliers, design complexity, increased variations) creates challenges. It is these challenges that trigger knowledge production. This also supports the other aspects of the study presented in earlier sections of this report.

6. Conclusions & Recommendations

This report has considered knowledge production, knowledge sources and capabilities in the construction industry. The main conclusions can be documented as follows.

- The construction industry is a knowledge based industry and the production of knowledge is vital for organisations and for projects.
- A variety of factors or triggers provide impetus for knowledge production in the construction industry. The main triggers of knowledge production are the need to address and solve problems; managing change; and managing innovation.
- There are different sources that individuals and organisations draw upon for knowledge production. These can be internal or external to the organisation. The main sources are:
 - other individuals,
 - the project team/supply chain,
 - organisational routines,
 - repositories,
 - communities of practice; and
 - knowledge gate-keepers.
- Knowledge production is a complex process which can occur through a number of ways (e.g. formal research, reflective practice, transformation and combination of existing knowledge). Reflective practice and, transformation and combination of existing knowledge are fundamental ways through which new knowledge is produced in the construction industry.
- Some aspects of the construction industry have been shown to act as promoters and inhibitors of knowledge production. The main promoting characteristics are:
 - A move towards change (e.g. quality improvement)
 - A move towards collaborative forms of procurement;
 - Enlightened clients.

- The inhibiting industry characteristics include:
 - reluctance to change (routines, etc.)
 - Confrontational, litigious, fragmented industry & organisations
 - Lack of trust
- There are aspects of project characteristics that promote and inhibit knowledge production. The main promoting factors are:
 - Effective team composition & high level of expertise
 - Presence of trust between team members/ team stability.
- The main inhibiting project characteristics are:
 - Ineffective team composition & low level of expertise
 - Scarce project resources (time, budget, etc.)
 - Lack of trust between team members/ team instability.
- Organisational culture influences knowledge production both positively and negatively. The main promoting aspects of organisational culture are:
 - An environment which promotes innovation to deliver better value
 - Willingness to embrace technological developments including IT
 - Awareness of the importance of KM including the provision of leadership.
- The main inhibiting aspects of organisational culture are:
 - Time pressure (e.g. limited time available to reflect on project knowledge during a project & from one project to the other)
 - Inward looking silo mentality
 - Reluctance to change & embrace new ideas & developments in the sector.
- Organisations produce knowledge at different rates to meet organisational needs. There is some evidence that a more concerted and formal approach, in places, may improve organisational knowledge production. For example, more formal meetings, brainstorming exercises, and better reflective and focused group sessions could be useful.

- Organisational capabilities play a vital role in knowledge production. For example, skilled and competent work-force is the key in knowledge production, especially in addressing problem solving situations, which is a trigger for knowledge production.
- With the organisational capabilities playing a vital role in knowledge production, organisations have an important role to play in improving the skills and competencies of their work-force. Appropriate and focused training programmes (e.g. CPD events, other short courses, in-house programmes- mentoring, coaching, job rotation) are important.
- With knowledge production being seen to be important, there needs to be a more concerted effort devoted to this aspect of KM by researchers. This should further improve our understanding of this area, with potential benefits for construction organisations.
- With problem solving, innovation and managing change being the main triggers of knowledge production, organisations should focus more on these issues and consider appropriate strategies for dealing with them.
- Organisations need to exploit a variety (and not a few) of sources, which they can draw upon for knowledge production. The identification of appropriate sources is important.
- As individuals are important sources for knowledge production, organisations need to put in place strategies for incentivization of employees. This should have the effect of motivating the individual's to share knowledge, thereby contributing to the wider knowledge production in the organisation.
- An environment which supports "trust building", promotes collaborative forms of working, reduces confrontational practices and embraces change, favours knowledge production. Organisations and individuals should strive towards creating that sort of an environment.

7. References

- Argyris, C., Schon, D.A., Payne, M. (1996) *Organisational Learning II: theory, method and practice*, Reading, MA: Addison-Wesley Pub Co.
- Argyris, C. and Schon, D.A. (1978) *Organisational Learning: a theory of action perspective*, Reading, MA: Addison-Wesley Pub Co.
- Bajaria, H.J. (2000) "Knowledge Creation and Management: inseparable twins." *Total Quality Management* 11(4):562-573.
- Boisot, M.H. (1998) *Knowledge Assets*, Oxford: Oxford University Press.
- Brooking, A. (1997) "The management of Intellectual Capital", *Long Range Planning*, vol. 30: 364-65.
- Ciborra, C.U. and Andreu, R. (2001) "Sharing Knowledge Across Boundaries." *Journal of Information Technology*, vol. 16:73-81.
- Cross, R. 1998. "Managing for Knowledge: managing for growth." *Knowledge Management* 1(3):9-13.
- Cross, R., Parker, A., Prusak, L. and Borgatti, S.P. (2001) "Knowing what we know: Supporting Knowledge Creation and Sharing in Social Networks." *Organisational Dynamics* 30(2):100-120.
- Davenport, T. and Prusak, L. (1998) *Working Knowledge: how organisations manage what they know?*, Boston: Harvard Business School Press.
- David Bartholomew and Associates, Gardiner & Theobald (2003) *Learning from Experience: the manual*, Final Report, Partners in Innovation Project (PII) (funded by the Department of Trade and Industry), UK.
- Despres, C. and Chauvel, D. (2000) "A Thematic Analysis of the Thinking in Knowledge Management", Pp. 55-86, in *Knowledge Horizons*, edited by C. Despres and D. Chauvel. Woburn, MA: Butterworth-Heinemann.
- Despres, C. and Chauvel, D. (1999) "Knowledge Management(s)." *Journal of Knowledge Management* 3(2):110-120.

Earl, M. (2001) "Knowledge Management Strategies: toward a taxonomy." *Journal of Management Information Systems* 18:215-233.

Edmondson, A., Moingeon, B. (1996) "When to Learn How and When to Learn Why: appropriate organisational learning processes as a source of competitive advantage." Pp. 17-37 *Organisational Learning and Competitive Advantage*, edited by B. Moingeon and A. Edmondson. London: Sage.

Egan, J. (1998) *Rethinking Construction*. London: DETR.

Egbu, C. and Botherill, K. (2001) "Knowledge Management and Intellectual Capital: benefits for project based industries", Proceedings of the Construction and Building Conference (CoBRA), London: RICS Foundation.

Ferlie, E. and Loch, I. (2001) *Change Management and Organisational Learning in Primary Care, Report to NHS Executive R&D (SE Region)*. London: The Management School, Imperial College.

Gibbons, M., Limoges C., Nowothy H., Schwartzman, S., Scott, P. and Trow, M. (1994) *The New Production of Knowledge*, London: Sage Publications.

Grant, R.M. (2000) "Shifts in the World Economy: the Drivers of Knowledge Management." Pp. 27-53, in *Knowledge Horizons*, edited by C. Despres and D. Chauvel. Woburn, MA: Butterworth-Heinemann.

Grant, R.M. (1991) "The Resource-based Theory of the Competitive Advantage: implications for strategy formulation." *California Management review* 34(Spring):114-135.

Greif, S., Keller, H. (1990) "Innovation and the Design of Work and Learning Environments." Pp. 231-250 *Innovation and Creativity at Work: psychological and organisational strategies*, edited by M. West and J.L. Farr. Chichester: John Wiley & Sons.

Hedberg, B. (2000) "The New Organisations: Managing Multiple Arenas for Knowledge Creation." Pp. 269-288 in *Knowledge Horizons*, edited by C. Despres and D. Chauvel. Woburn, MA: Butterworth-Heinemann.

Hedlund, G. (1994) "A Model of Knowledge Management and the N-form Corporation." *Strategic Management Journal* 15:73-90.

Ives, W., Torrey, B. and Gordon, C. (1998) "Knowledge Management: an emerging discipline with a long history." *Journal of Knowledge Management* 1(4):269-274.

Kamara, J.M., Anumba, C.J. and Carrillo, P.M. (2002) "A CLEVER Approach to Selecting a Knowledge Management Strategy." *International Journal of Project Management* 20(3):205-211.

Krogh, G.v., Ichijo, K. and Nonaka, I. (2000) *Enabling Knowledge Creation: how to unlock the mystery of tacit knowledge and release the power of innovation*, Oxford: Oxford University Press.

Kululanga, G.K., McCaffer, R. (2001) "Measuring knowledge management for construction." *Engineering Construction and Architectural Management* 8:346-354.

Latham, M. (1994) *Constructing the Team: final report*, London: HMSO.

McAdam, R., McCreedy, S. (1999a) "A Critical Review of Knowledge Management Models." *The Learning Organisation* 6(3):91-100.

McAdam, R., McCreedy, S. (1999b) "The Process of Knowledge Management within Organisations: a critical assessment of both theory and practice." *Knowledge and Process Management* 6:101-112.

Nonaka, I., Reinmoeller, P. and Senoo, P (2000) "Integrated IT Systems to Capitalize on Market Knowledge." Pp. 89-112 *Knowledge Creation: a source of value*, edited by Krogh, G. von, Nonaka, I. and Nishiguichi, T., Basingstoke, London: Macmillan.

Nonaka, I., Takeuchi, H. (1995) *The Knowledge Creating Company: how Japanese companies create the dynamics of innovation*, Oxford: Oxford University Press.

Nonaka, I., Toyama, R. (2000) "SECI, Ba and Leadership: a unified model of dynamic knowledge creation." *Long range planning* 33:5-34.

Nonaka, I., Nishiguchi T. (eds) (2001) *Knowledge emergence: social, technical, and evolutionary dimensions of knowledge creation*, Oxford: Oxford University Press.

Quintas, P. (2002) "Knowledge Management in the 21st century", in *Deciphering Knowledge Management*, edited by Clegg, Booth, Clarke & Sominan. New York: Springer Verlag.

Salisbury, M. (2001) "An Example of Managing the Knowledge Creation Process for a Small Work Group." *Management Learning* 32(3):305-319.

Schein, E.H. (1996) "Three Cultures of Management: the key to organisational learning." *Sloan Management Review* Fall:9-20.

Stacey, R.D. (2001) "Complex Responsive Processes in Organisations: learning and knowledge creation."

Sverlinger, P.M. (2000) "Managing Knowledge in Professional Service Organisations." Department of Service Management, Chalmers University of Technology, Goteborg, Sweden.

Van der Spek, R., Spijkervet, A. (1997) "Knowledge Management: dealing intelligently with knowledge", in *Knowledge Management and Its Integrative Elements*, edited by Liebowitz, J., Wilcox, L., London: CRC Press

Venters, W. (2002) "Literature Review for C-Sand: Knowledge Management" available on-line at <http://www.c-sand.org.uk/Documents/WP1001-02-KMLitRev.pdf>

von Krogh, G., Grand, S. (2000) "Justification in Knowledge Creation: dominant logic in management discourses." Pp. 13-35 *Knowledge Creation: a source of value*, edited by G. von Krogh, I. Nonaka and T. Nishiguchi. Basingstoke, London: Macmillan Press Ltd.

Wiig, K.M. (2000) "Knowledge Management: an emerging discipline." Pp. 3-26 *Knowledge Horizons: the present and the promise of knowledge management*, edited by C. Despres and D. Chauvel. Woburn, MA: Butterworth-Heinemann.

Wiig, K.M. (1993) Knowledge Management Foundation, New York: Schema Press.

8. Appendix 1

Areas Covered During the Semi-Structured Interviews

Explain the project very briefly. Re-assure the respondent on the CONFIDENTIALITY issues.

Explain the format of the interview (open ended questions, no right-wrong answer)

Interviewees Role & his/her nature of work.

Knowledge production

<p>Ascertain whether the respondent faced a challenging situation which triggered knowledge production.</p> <p>Ascertain whether the respondent faced a novel situation which triggered knowledge production.</p>	<p>Knowledge production:</p> <p>Triggers</p> <p>Process:</p> <ul style="list-style-type: none"> • How does k- come about? • Did s/he attempt to find out whether the kind of knowledge already existed in the organisation, project team, supply chain, etc.? <p>Sources</p> <p>Outputs</p>
---	---

Influences of the Characteristics of the Construction Industry on Knowledge production

How do the characteristics of the construction industry influence knowledge production?

POSSIBLE FACTORS	
DIFFICULTY	EASE
<p>Adversarial nature of construction contracts</p> <p>Low trust among project partners</p> <p>Uniqueness (one-off) nature of problems which require one off solutions</p> <p>Nomadic nature of people</p> <p>Low stakes</p> <p>Low motivation/incentives, Etc. etc.</p>	<p>Partnering</p> <p>Framework agreement</p> <p>Repeat/enlightened client</p> <p>Stable team</p> <p>Competent work force</p> <p>Similar absorption capacity of work force, Etc. etc.</p>

Influences of the Project Characteristics on Knowledge production

How do the characteristics of individual projects influence knowledge production? In other words, does the ease/difficulty of knowledge production change from one project to another?

Influences of Organisational Culture on Knowledge production

How do you think the organisational culture influence knowledge production?

In an ideal situation, which organisational changes would facilitate the knowledge processes?