Knowledge Mapping Techniques Within The Construction Industry:An Exploratory Study

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Abstract

The last 15 years has seen the transitioning of the industrial economy to a knowledge economy. Knowledge is now considered as the new value proposition of the post-industrial economy, which is embedded in staff and workers in the organization; and can and should be considered a key resource for competitiveness and performance. Organisations intending to effectively exploit their knowledge assets might need to effectively identify where their knowledge resides. This is the underlying principle of "knowledge mapping". Knowledge mapping techniques aim to track the acquisition and loss of information and knowledge. It explores personal and group competencies and illustrates how knowledge flows throughout an organisation or 'network'. This paper reports some of the findings from an Engineering and Physical Sciences Research Council (EPSRC), UK, funded project entitled "Knowledge mapping and bringing about change for the sustainable urban environment". This research project investigated the different types of knowledge mapping techniques that are used to bring about change from a sustainable urban environment (SUE) perspective.

Semi-structured interviews were conducted with fourteen (14) construction industry actors (architects, developers, and main contractors) and four (4) developers of knowledge mapping software tools to identify current and 'successful' knowledge mapping tools. The semi-structured interviews investigated the mechanisms by which the construction industry actors learn (both from their experiences and from external sources of knowledge), capture knowledge and know-how and diffuse it across organisations. The interviews with software developers investigated the types of knowledge mapping tools on the market, focusing on their dynamism and potential effects for the users. Of particular interest were the capture and diffusion of knowledge and know-how related to sustainability, which was defined broadly in terms of the triple bottom line (Economic, Social and Environmental). The paper concludes that the construction industry stakeholders interviewed accept that knowledge mapping is important and have initiated or improved mechanisms (tools/techniques) to capture and diffuse information, particularly with respect to sustainability. However, generally speaking, they have not adopted off-the peg knowledge mapping software solutions. The market solutions are not seen to be cost effective, do not offer the firms added value and organisations prefer instead to invest in in-house development of intranets and other IT enabled tools. They also rely on techniques long established in the firm (e.g. meetings, briefing notes, seminars, coaching schemes, and newsletters). This study revealed that the industry actively uses different combinations of nine out of the seventeen knowledge mapping tools identified.

Keywords: Knowledge, knowledge management, knowledge mapping, sustainable urban environment

1. Introduction

A new focus of interest has emerged with the transitioning of the industrial economy into what Drucker [3] refers to as the 'knowledge economy.' In his pioneering work, he advanced the notion that knowledge is the new value proposition of the post-industrial economy, that it is embedded in members of an organisation, and that it can and should be considered a key resource for competitiveness and performance. However, Suresh [11] has shown that there is an urgent need for improved awareness and understanding of the challenges and significance of knowledge management in the construction industry. The construction industry is characterised by a wealth of experiential knowledge, yet senior staff retire or leave organisations regularly, potentially taking tacit knowledge and a potential source of competitive advantage with them. Organisations should decide how best to cope with this problem, so that as much knowledge as possible is retained within organisational boundaries. Organisations intending to effectively exploit their knowledge assets might need to effectively identify where their knowledge resides.

Knowledge management (KM) consists of distinct but interrelated processes that are not linear but can be iterative. Suresh [11] defines KM as "a process by which knowledge is identified, captured, codified, stored, disseminated (shared/ transferred), implemented (adapted, transformed, synthesised) and its impact measured for the benefit of an organisation".

Renukappa and Egbu [10] indicated that knowledge mapping is the field within knowledge management (KM) that aims to optimise the efficient and effective use of organisation's sustainability-related knowledge. Speel et al. [8] define knowledge mapping as the process, methods and tools for analysing knowledge areas in order to discover features or meaning and to visualise these in a comprehensive, transparent form, such that the business-relevant features are clearly highlighted. Knowledge maps are created by transferring certain aspects of knowledge into a graphical form that is easily understandable. Knowledge mapping techniques aim to track the acquisition and loss of information and knowledge. It explores personal and group competencies and illustrates how knowledge flows throughout an organisation or 'network'.

The challenge of knowledge mapping is to understand how to create practical solutions to support individuals and groups as they generate or acquire this multi-faceted knowledge so as to suit the particular requirements of their application context [9]. Organisations must also grow the capability to share knowledge between specialised areas and across internal and external boundaries. The ability to generate new technological knowledge is now viewed to be linked to a specific learning capability which draws from diverse knowledge bases and is able to activate a systemic recombination process [1]. In all these, identifying the sets of knowledge that will make the greatest difference, where they reside and how they can be accessed and exploited for team, organisational and communal benefits are fundamental. This is integral to the issue of knowledge mapping.

A knowledge map can also serve as an inventory. It is a 'picture' of what exists in an organisation or a 'network' of where it is located. It therefore can be used as a tool to evaluate

the corporate knowledge stock (e.g. knowledge for sustainability) revealing strengths to be exploited and gaps that need to be filled [2]. A thorough literature review leads to the identification of seventeen knowledge mapping techniques. These knowledge mapping tools and techniques are:

1. Concept map
2. Mind Map /Idea map
3. Concept circle diagram
4. Semantic map
5. Cognitive map
6. Process map
7. Social mess map / Cross boundary causality map
8. Conceptual map
9. Knowledge flow map
10. Causal map
11. Ontology
12. Petri net
13. Cluster Vee diagram
14. Thesauri
15. Visual thinking network
16. Topic map
17. Perceptual map

The dynamics of knowledge mapping can be just as important, particularly where change is an important issue. Dynamic approaches to modelling and mapping consider the flow of knowledge - how it is created, distributed and accessed - as much as the knowledge itself. The research work sought to appraise the options for knowledge mapping tools which would meet this need. The results were then used as the basis for selection and implementation of knowledge mapping tools/ techniques. At the same time, a structured method to assess and evaluate the efficacy of these knowledge mapping tools against some identified criteria was developed. This is discussed in section 4 of this paper.

2. Project description

This paper describes the findings of a 6-month project entitled “Knowledge Mapping and Bringing About Change for the Sustainable Urban Environment”, involving Glasgow Caledonian University, Open University, University of Manchester, London South Bank University and Cambridge University as academic partners. The non-academic partners included Sustainability Centre in Glasgow (SCG), Laing O’ Rourke Scotland, Dearle and Henderson, Centre for the Built Environment (CBE, Glasgow), Caledonian Shanks (now Caledonian Environment Centre) and the Building Services Research and Information Association (BSRIA). Both the authors were part of the Glasgow Caledonian University research team.

3. Research methodology

The overall research process used in the project is given in Figure 1. The project was given direction through its 'research aims and identifiable objectives'.

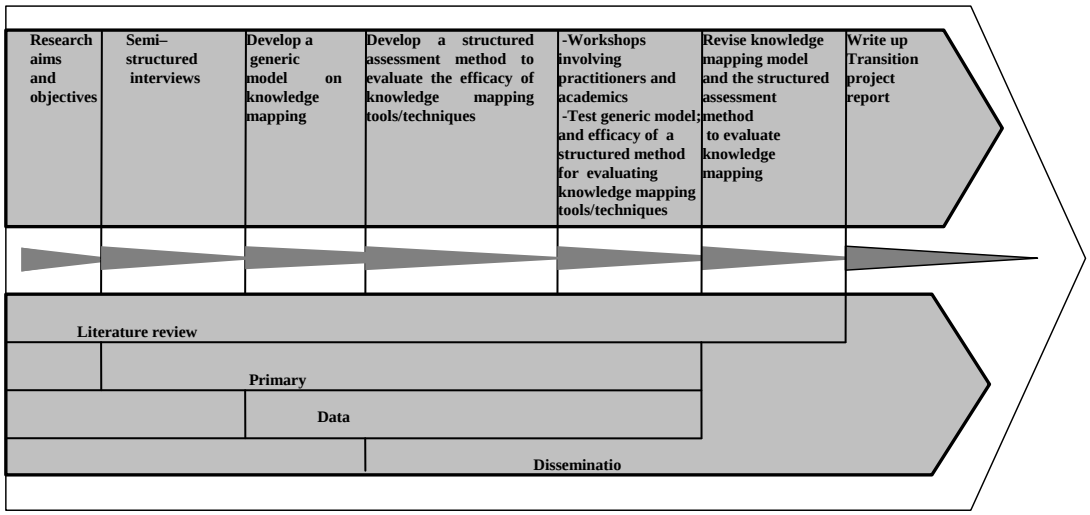

Figure 1: Project Research Methodology

In this paper literature review, primary data collection and analysis is discussed. A total of 18 semi-structured interviews were conducted. Semi-structured interviews were conducted with fourteen (14) construction industry actors (architects, developers, and main contractors) and four (4) developers of knowledge mapping software tools to identify current and 'successful' knowledge mapping tools. The semi-structured interviews investigated the mechanisms by which the construction industry actors learn (both from their experiences and from external sources of knowledge), capture knowledge and know-how and diffuse it across the organisation. The interviews with the software developers investigated the types of knowledge mapping tools on the market, focusing on their dynamism and potential effects for the users. Of particular interest were the capture and diffusion of knowledge and know-how related to sustainability, which was defined broadly in terms of the triple bottom line (Economic, Social and Environmental).

The response of each individual interviewees of a particular topic was put together. The questions asked during the semi structured interviews were:

- What tools and techniques do you use for recording and using knowledge and know-how sourced from within the organisation (or on the project you're working on) and from outside the organisation?

- How did this tool/technique come about (i.e. from where did the tool/technique originate) and when was it first used?

- How has the tool/technique changed (i.e. evolved) since its first use?

- How has it brought about change (both positive and negative) in your organisation?
- What impact (in terms of its value) has the tool/technique had and how do you measure its impact/value?
- What is the scope of the tool/technique and what are its limitations?
- Do you need training to use the tool/technique? How many (or what proportion) of the workforce (project workforce) use the tool?

The data collected from the eighteen (18) interviews were analysed using content analysis. Soetanto et al. [7] describes content analysis as a technique for extracting and categorising information from the text. Neuman [6] describes content analysis as a technique for gathering and analysing the content of text. Guthrie et al. [4] describe content analysis as a technique for gathering data, involves codifying quantitative and qualitative information into pre-defined categories in order to derive patterns in the presentation and reporting of information. Content analysis according to Neuman [6], Soetanto et al. [7] is a research tool used to determine the presence of certain words or concepts within the texts or sets of texts. Researchers quantify and analyse the presence, meanings and relationships of such words and concepts, and making inferences about the messages within the texts, interviews, discussions, essays, book chapters, articles, speeches or any occurrence of communicative language.

According to Guthrie et al. [4], for content analysis to be effective, certain technical requirements should be met. First, the categories of classification must be clearly and operationally defined. Second, the objective of the study should be clear. Third, the information needs to be able to be quantified and finally, a reliable coder is necessary for consistency. To conduct a content analysis of any such text, the text is initially transcribed, generalised and coded or broken down into manageable categories of levels using one of the content analysis' basic methods: conceptual analysis or rational analysis [4]. In conceptual analysis method, a concept is chosen for examination, and the analysis involves quantifying and tallying its presence. This is also known as thematic analysis or manifest content [5]. In rational analysis method, like conceptual analysis, it begins with the act of identifying concepts that are present in a given text or set of texts but seeks this by exploring the relationships between the concepts identified. This is also known as semantic analysis and is regarded as latent content by McBurney [5] where the focus is to look for semantic or meaningful, relationships.

Conceptual analysis, which was employed in the study reported in this paper, begins with identifying objectives and the text must be coded into manageable content categories. By reducing the text to categories consisting of a word, set of words or phrases, the researcher can focus on, and code for, specific words or patterns that are indicative of the research objectives. The researcher decides on how many different concepts to code for. This involves developing a

pre-defined or interactive set of concepts and categories. After a certain numbers, sets of concepts are chosen for coding.

4. Knowledge mapping techniques within the construction industry

The interviews highlighted that knowledge mapping was deemed to be important and that the organisations had some (simple) knowledge mapping tools and techniques in place. The distinction between knowledge mapping tools and techniques is that the former is IT enabled. All the construction organisations interviewed use a combination of different knowledge mapping tools. For instance, in terms of tools:

- In-house created intra-nets – A combination of idea and casual maps were employed by ten (10) organisations to create the so-called "linchpin" of knowledge capture and diffusion, including both internal knowledge (e.g. facilitating 'communities of practice' – often through an interactive virtual bullet board – and promoting 'top tips' and highlighting 'best practice') and external knowledge (e.g. new regulations, new technologies, links to relevant external magazine articles, external websites, conference proceedings). Interviews revealed that company intranets are often administered centrally but information can be uploaded de-centrally. Also, intranets are often group-wide but contain mini-intranets organised by function or location.
- In-house created on-line database libraries – A combination of concept, cognitive and casual maps were identified in all the organisations interviewed. But these are seen as less interactive than intranets, more a repository for structured material, but advanced (and ICT enabled) in terms of search facilities (e.g. 7500 search terms in one instance) and decentralised in terms of allowing the uploading of information from projects and site managers. These often contained end of project reports, documents describing new in-house procedures, profiles of persons with knowledge/experience in a particular area.

In terms of techniques, a combination of social mess and knowledge-flow maps were identified in eight (8) organisations with much emphasis placed on the diffusion of knowledge through human interaction ("the most effective method of transferring knowledge", argued one respondent). This is used mainly within an organisation but it sometimes involves the occasional use of experts from outside the organisation (from industry organisations e.g. CIRIA and cross industry organisations). Other knowledge mapping techniques identified are:

- The use of semantic/ perceptual maps by teams dedicated to visiting sites, capturing ideas and best practice and diffusing them via on-site demonstrations: the teams included 'environmental consultants' or 'continuous performance engineers';
- Technical help lines, where calls are monitored and trends (common issues, problems) identified;
- Coaching from people with recent experience or expertise in industries, products, concepts (again, sometimes external experts were involved); regular meetings between senior management and divisional/project managers; a form of knowledge flow map (to diffuse information across and up/down the organisation) or between experts e.g. environmental advisors (to share specific knowledge);
- 'Working party' groups to investigate common problems and diffuse knowledge;

- Training programmes including lunch-time seminars on specific topics (again, sometimes with external consultants);
- Peer reviewed and externally published papers; a depiction of process map;
- Technical newsletters, which raise issues, describe best practice, advertise seminars and promote top tips.

Most of the tools and techniques described above were implemented in an attempt to improve efficiency (productivity) and sustainability (often environmental and health and safety knowledge). In one instance, tools were implemented in response to an employee leaving the organisation. Interviews revealed that some organisations had attempted to measure the success of the tools. Tangible measures, such as Key Performance Indicators on health and safety, and on design, were used to monitor the success of tools (i.e. an 'output' measure) but more often the interviewees described the more intangible benefits of the tools e.g. encouraging a group spirit (across decentralised and diversified contractors), embedding a gender of sustainability in the organisation, and lowering risks (by providing 'digestible' information). In most cases, tools had been in place for a number of years and had teams dedicated to keeping the tools up-to-date (including correcting problems).

Most tools did not require staff training and were designed with user friendliness in mind. However, issues of user friendliness were identified as a hindering factor by a number of organisations. Other factors hindering the effectiveness of the tools were problems with recording or codifying/visually representing the information (e.g. transferring it from people's minds to the page), software quality (e.g. inadequate keyword searches), targeting information to relevant users, and over-coming routines (i.e. "the way we do things around here"). The knowledge mapping products marketed by the software developers were closer to some of the more sophisticated knowledge mapping tools identified in the review of literature. However, notwithstanding the experience of one large contractor, these were largely not used by the interviewees. In fact, the knowledge mapping tools offered by the interviewees were designed in-house and were considerably simpler than those described by the software developers. Those offered by the software developers were platforms for visualising and organising ideas (e.g. Axon Idea Processor, Mind Technologies' Visual Mind, Mindjet Corporation's MindManager X5, CoCo Systems' Visi Map Professional). These tools are electronic versions of some of the knowledge mapping tools such as concept maps, mind maps, and cross boundary causality maps.

Table 1 presents the most used knowledge mapping tools/ techniques which are perceived to be most successfully used by construction industry actors and software developers. The study also revealed that the industry actively uses different combinations of nine out of the seventeen (i.e. those in Table 1) knowledge mapping tools identified in the study. The dynamic mapping of knowledge requires the identification of temporal properties of the content elements and of ways to map them in a dynamic manner. Examples of temporal properties of maps are time, duration, or behaviour. All the tools and techniques investigated might present dynamic characteristics (adaptable to change) however, the cost of adjustment to change (time) may prove prohibitive in some cases. It is therefore necessary to consider the cost benefit analysis prior to designing or choosing the tool/technique.

Table 1: Knowledge mapping tools/techniques in construction industry actors and software developers

Sl NO	Knowledge Mapping Tools/ Techniques	Construction Industry Actors	Software Developer
1.	Casual Map	✓	✓
2.	Cognitive Map	✓	
3.	Concept Map	✓	✓
4.	Knowledge Flow Map	✓	
5.	Mind/ Idea Map	✓	✓
6.	Perceptual Map	✓	
7.	Process Map	✓	✓
8.	Semantic Map	✓	
9.	Social Mess Map	✓	

The knowledge mapping tools/techniques purport to stimulate creativity, allow one to see the big picture, help organise your time and share your thoughts, and improve understanding. One large contractor has adopted a 'mind mapping' software and has used it to facilitate workshops, brainstorming sessions and meetings (e.g. communicating more effectively agendas for meetings, business planning, goals and objectives). According to one interviewee, it has made meetings more productive (e.g. notes are taken during the meeting and exported directly into a minutes' template) and helped overcome problems of individuality (i.e. making the outcome of meetings a group effort). Adoption of the mind mapping software in this instance stemmed from a 'champion' in the organisation, who is also the Knowledge Manager in the company have had some experience of using the software at University and is trying to encourage its adoption across the organisation. However, notwithstanding individual champions, the interviews revealed that these more sophisticated knowledge mapping tools were not used pervasively across the construction industry. This begs the question of why the software developer tools (or similar platforms) are not diffused more widely. From the interviews, one can infer that these tools far exceed the companies' requirements. Indeed, some of the functions are provided by other tools (e.g. IT and telecommunications products/services) and techniques (e.g. meetings, brainstorming). It is likely also that they may exacerbate (or at least be perceived to potentially exacerbate) the problems already hindering the diffusion of current simpler systems.

The study also sought to ascertain the efficacy of the knowledge mapping tools and techniques; and document what factors are being considered by users in choosing and using knowledge mapping tools/techniques. The key factors considered by users of knowledge mapping tools and techniques in the construction industry are robustness, cost, user friendliness, dynamism, the low level of training needed before their use, the degree of positive impact the tool/technique is likely to make on their businesses (processes, services and products) as well as their level of flexibility and adaptability. Table 2 summarises the perceptions of those interviewed with regard to how they evaluated the nine most used tools/techniques. The three scales of 'High', 'Medium' and 'Low' were used in the evaluation. For example, the Social Mess Map technique was rated high in terms of robustness, cost, user friendliness but low in terms of how adaptable or flexible it is.

Table 2: Structured assessment for knowledge mapping tools/techniques – construction industry perspective

Evaluation criteria	Knowledge mapping tools/techniques								
	Casual map	Cognitive map	Concept map	Knowledge flow map	Mind/Idea map	Perceptual map	Process map	Semantic map	Social mess map
Robustness	Medium	Low	High	High	High	Medium	High	High	High
Cost	Low	Medium	Low	Low	Medium	Low	Low	High	High
User friendliness	High	Medium	Medium	High	Medium	High	Medium	High	High
Dynamism	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
Training	Low	Low	Medium	Low	Medium	Low	Medium	Low	Low
Impact	Medium	Medium	Low	Medium	High	Medium	High	Medium	High
Adaptability	Medium	Medium	Low	Low	Low	Medium	Low	Medium	Low

5. Conclusions

The paper concludes that the construction industry stakeholders interviewed accept that knowledge mapping is important and have initiated or improved mechanisms (tools/techniques) to capture and diffuse information, particularly with respect to sustainability. However, generally speaking, they have not adopted off-the peg knowledge mapping software solutions. The market solutions are not seen to be cost effective, do not offer the firms added value and organisations prefer instead to invest in in-house development of intranets and other IT enabled tools. They also rely on techniques long established in the firm (e.g. meetings, briefing notes, seminars, coaching schemes, and newsletters). This study revealed that the industry actively uses different combinations of nine out of the seventeen knowledge mapping tools identified.

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