Knowledge management in construction supply chain integration

Malik M.A. Khalfan*
School of Property, Construction and Project Management
RMIT University, GPO Box 2476V
Melbourne, VIC 3001, Australia
E-mail: malikmansoorali@hotmail.com
*Corresponding author

Mukesh Kashyap
School of Architecture, Design and the Built Environment
Nottingham Trent University
Burton Street, Nottingham
Nottinghamshire, NG1 4BU, UK
E-mail: mukesh.kashyap@ntu.ac.uk

Xianguang Li
Institute of Construction Management and Real Estate
Department of Construction Management and Real Estate
Southeast University
Nanjing 210096, China
E-mail: xianguangli@yahoo.com

Carl Abbott
School of Built Environment
Salford Centre for Research and Innovation
BuHu Research Institute
University of Salford
4th Floor, Maxwell Building
Salford, Greater Manchester, M5 4WT, UK
E-mail: C.Abbott@salford.ac.uk

Abstract: Knowledge Management (KM) is becoming increasingly important for organisations across a wide spectrum of industry sectors, especially for the naturally fragmented construction industry. There has been a growing realisation that it is very important for each project participant to effectively capture, share and utilise strategic knowledge and project knowledge, as well as process knowledge within the construction supply chain for better performance. This paper highlights the benefits of integrated construction supply chain management through effective KM. The paper reviews the general literature in construction supply chains and KM and presents some initiatives in...
the abovementioned area, followed by a full theory analysis and case study. The case study was conducted with a public sector client organisation in the UK. It explored their strategies for an integrated construction supply chain through KM, knowledge capture and knowledge sharing. It also studied the reuse by their employees as well as by the other organisations they worked with to deliver construction projects in north-west England. The paper concludes that KM would effectively improve the integration of construction supply chains and thus improve overall production performance.

Keywords: supply chain integration; knowledge management; public sector clients; community of practice; CoP.


Biographical notes:
Dr. Malik M.A. Khalfan joined Loughborough University, UK, after the completion of his PhD in 2001 and was involved in an EPSRC-funded project as a Research Associate. He is currently working at the Salford Centre for Research and Innovation (SCRI) of the University of Salford as a Senior Research Fellow. His research interests include the readiness assessment of concurrent engineering in construction, sustainable construction, knowledge management in construction, supply chain management and procurement within the construction industry. He has more than 75 publications on the abovementioned research areas. He was the winner of CIOB Innovation Award 2000 for the Best Research Paper.

Dr. Mukesh Kashyap is a Senior Lecturer at Nottingham Trent University, UK. He has over 15 years of construction experience in building and civil engineering projects in India, Nigeria and the UK. He holds a degree in Civil Engineering, a Postgraduate degree in Construction Project Management and a Doctorate from Loughborough University. He is a member of the Association for Project Management, an associate member of the Chartered Management Institute and member of the CIOB. He is presently the Chair of the CIOB East Midlands branch and sits on the Members’ Forum. His current research interests include construction health and safety, innovation in construction, supply chain and knowledge management.

Xianguang Li is a PhD candidate at Southeast University (SEU), China, majoring in Construction Management. He is currently an academic visitor at SCRI at the University of Salford, UK. He obtained his Bachelor’s degree in Civil Engineering from Henan Polytechnic University in 2003 and Master of Science from Guizhou University in 2006. He has published 11 papers in national/international journals and conferences. He received full funding to undertake his PhD in the UK for his outstanding research work. His research interest mainly focuses on construction supply chain management and competitiveness.

Carl Abbott is a Senior Research Fellow at the University of Salford, UK, and the Manager of the EPSRC-funded Salford Centre for Research and Innovation in the Built Environment (SCRI). He initially qualified as an Electronics Design Engineer with British Aerospace and was a Lecturer in Electronics. He then joined the University of Salford in 1999 to research IT in construction and worked closely with regional industry to establish the Centre for Construction Innovation, where he was the General Manager. His current research interests include innovation, offsite manufacture, benchmarking and ICT.
1 Introduction

For the last few years, researchers and practitioners have adopted different concepts and theories from other industries to bring improvements within the construction industry. Knowledge Management (KM) is one of those concepts recognised as a core business concern and intellectual assets playing a vital role in gaining competitive advantage (Xianguang et al., 2007b). In the construction industry, it is important to manage the project, process and product related knowledge (Robinson et al., 2005). Once captured, such knowledge becomes part of the organisation’s knowledge and can be shared, disseminated, and even used to create new knowledge. Supply chain management is another concept adopted and being translated to suit the construction industry. The recent emphasis is on the integration of numerous participants in the supply chain. To deal with the fragmented nature of the industry Khalfan et al. (2005) have concluded that the more knowledge about businesses of the participants in a supply chain, the more integrated that supply chain is. Supply chain integration through effective KM will be discussed in detail in the light of industrial experiences here. This paper develops a general literature review to discuss and explore the concept of KM with supply chain management within the construction industry and presents some initiatives in the above mentioned areas. The paper utilised the findings of case studies undertaken by the Construction Supply Chain Management research team at the Salford Centre for Research and Innovation (SCRI) Research Centre to support the proposition that the supply chains tend to fall apart and do not work effectively if the KM across the chain is not properly implemented, and vice versa. The paper also briefly discusses a proposed framework to enable the integration of construction supply chain as well as supply chain management research focus within the overall initiative.

2 Supply chain management and integration in construction Industry

2.1 Construction supply chain management

Construction supply-chain management offers new approaches to reduce the cost and increase the reliability and speed of facility construction. Dainty et al. (2001) described supply chain management as the management of a network of organisations which are involved in carrying out the business process. In the construction industry, often these networks can be of extremely complex nature because of the large number of separate organisations involved on a large project (Briscoe et al., 2001). Figure 1, taken from Briscoe et al. (2001) displays a typical construction supply network (only the main elements), with the main contractor at the centre of the hub.

There are two primary schools of thoughts within supply chain management theory within the construction industry. The first is associated with logistics theory to reduce waste through efficient management of flow of supply of materials on a construction site. This view concentrates on the logistics of construction process, and views supplier interaction as clusters of subcontractors concentrated around the main contractor. Bertelsen (1997) also looked at construction supply chain from a logistics point of view. He concluded that a substantial increase in productivity can be obtained by delivering and handling building materials efficiently based on conditions dictated by a construction site. These could be ‘Just-in-Time’ (JIT), and ‘packed for the work process’. The additional
cost incurred using these approaches can easily be covered by the savings gained on construction site. The second school is associated with lean thinking and seeks to create value across the entire chain of supply (London et al., 1998). The supply chain management on the other hand focuses on understanding and improving the coordination of multiple firms that compose a supply chain (O’Brien et al., 2002). Figure 2 describes a conceptual view of a construction supply chain. However, this figure does not give an indication of the complexity of supply chain production operations.

**Figure 1** A typical construction supply chain

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### 2.2 Construction supply chain integration

The supply chain in construction can be considered as a process of a series of activities transforming raw materials into finished products. Unlike other industrial sectors, the construction industry consists of three distinct but interdependent supply chains, namely: professional services; building and assembly; and materials supply (Cox and Thompson, 1998). With the traditionally adversarial contractual nature of relationships in construction projects, and fragmented production environment, the construction industry faces strong barriers to supply chain integration (Li et al., 2007b). This predicament always results in ineffective, inefficient, and inadequate mechanisms to deliver good services and profitability. Briscoe and Dainty (2005) pointed out that integration initiated by project stakeholders may appear in different forms depending on the level of integration, specific construction sub-sector and type of project. Higher levels of integration within the supply chain have been coined to lead to higher levels of effectiveness and efficiency. Some recent evidence suggests that there are opportunities for improving integration practices although it usually is an elusive goal. Murray et al. (1999) maintained that long-term strategic partnerships hold the key to integration and sought to show how such relationships could overcome the temporary nature of one-off projects and provide a measure of continuity in the supply chain. However, Cox and Ireland (2002) argue that effective construction supply chain management requires approach developed on circumstances of the firm rather than just collaboration and
integration. Childerhouse et al. (2003) have shown how the UK house building sector, despite responding late to the compelling need for change and starting its business process reengineering from a relatively poor baseline has remarkably developed supply chains to embrace the principles of integration. Similarly, Humphreys et al. (2003) showed a new approach by a main contractor by establishing qualified partnering with subcontractors that has yielded improvement in terms of integration. There is also growing realisation that KM drives and enables the construction supply chain integration.

**Figure 2** Conceptual view of the construction project supply chain (see online version for colours)

Source: O’Brien et al. (2002)

### 2.3 Knowledge management for construction supply chain integration

KM is defined as any process or practice of creating, acquiring, capturing, sharing and using knowledge, to enhance learning and performance in an organisation (Scarborough et al., 1999).

Defining knowledge precisely can be problematic since the researchers still debate the single unified definition of the concept (Nonaka and Takeuchi, 1995; Stewart, 1997; Boisot, 1998). However, it is widely agreed that knowledge is a valuable yet frequently intangible asset (Tiwana, 2000), and that there are several dimensions of knowledge, i.e., individual and group knowledge, internal and external knowledge, tacit (know-how that is stored in people’s head) and explicit (documented and publicly available) knowledge (Nonaka and Takeuchi, 1995; Duffy, 2000; Al-Ghassani et al., 2002). Different views of knowledge lead to different perceptions of KM. Overall, KM is largely regarded as a process involving various activities. Generally, it includes the four basic processes of creating, storing/retrieving, transferring, and applying knowledge. These major processes can be subdivided, for example, into creating internal knowledge, acquiring external knowledge, storing knowledge in documents versus storing in routines (Teece, 1998) as well as updating the knowledge and sharing knowledge internally and externally (Alavi and Leidner, 2001).

KM generally deals with the systematic and organised attempt to use knowledge within an organisation to transform its ability to store and use it to improve performance (KPMG, 1998). The importance of KM for the construction industry has widely been acknowledged by various researchers (Egbru, 2002; Carrillo et al., 2003; Carrillo, 2004).
Other important research works conducted to improve the understanding of KM mechanisms within the construction industry include; the provision of a KM framework (Kamara et al., 2002), the impact of KM on construction innovation (Egbu et al., 2001), the effect on business processes and performance (Preece et al., 2000), the role of IT to improve KM (Carrillo et al., 2000; Patel et al., 2000), and mechanism to improve knowledge transfers between construction organisations (Fernie et al., 2001).

Integrated KM mechanisms can help to improve the organisational performance and business processes of the supply chain partners. According to Mertins et al. (2001), for the construction supply chain, KM can result in providing an understanding of markets and customers; developing visions and strategies; developing products and services; improvements in marketing and sales as well as the production and distribution of products and/or services. For a construction supply chain this may include process and product improvements by sharing knowledge among the supply chain partners, reduced costs as a result of centralised communication among collaborating partners, or increased profits by using centralised knowledge as a source of competitive advantage to win new or repeat businesses.

An understanding of the concept of knowledge and knowledge taxonomies is important because theoretical developments in the KM area are influenced by the distinction among the different types of knowledge (Alavi and Leidner, 2001). The knowledge taxonomies discussed here can inform the design of KM systems to improve the construction supply chain by calling attention to the need for support of different types of knowledge and the flows among these different chains. KM may provide an opportunity for extending the scope of IT-based knowledge provision. Different knowledge types, their characteristics and examples supporting construction supply chain integration are summarised in Table 1.

### Table 1  
Knowledge types and examples supporting construction supply chain integration

<table>
<thead>
<tr>
<th>Knowledge types</th>
<th>Characteristic</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tacit</td>
<td>Knowledge is rooted in actions, experience, and involvement in specific construction project</td>
<td>Individual’s belief on cause-effect relations within construction supply chain integration</td>
</tr>
<tr>
<td>Explicit</td>
<td>Articulated, generalised knowledge</td>
<td>Knowledge of major partners within construction industry</td>
</tr>
<tr>
<td>Individual</td>
<td>Created by and inherent in the individual</td>
<td>Insights gained from completed project</td>
</tr>
<tr>
<td>Social</td>
<td>Created by and inherent in collective actions of a group</td>
<td>Norms for supply chain communication</td>
</tr>
<tr>
<td>Declarative</td>
<td>Know-about</td>
<td>Which partner is responsible for this task</td>
</tr>
<tr>
<td>Procedural</td>
<td>Know-how</td>
<td>How to cooperate with a partner (e.g., subcontractor)</td>
</tr>
<tr>
<td>Causal</td>
<td>Know-why</td>
<td>Understanding why partner respond in a specific way</td>
</tr>
<tr>
<td>Conditional</td>
<td>Know-when</td>
<td>Understanding when to ask supplier to transport construction materials to site</td>
</tr>
<tr>
<td>Relational</td>
<td>Know-with</td>
<td>Understanding how the partners interact with each other</td>
</tr>
<tr>
<td>Pragmatic</td>
<td>Useful knowledge for an organisation</td>
<td>Construction best practices, construction procurement route, project experiences, engineering drawings, and so on</td>
</tr>
</tbody>
</table>

*Source: Adapted from Alavi and Leidner (2001)*
It is now becoming necessary to know more about people, project and processes because
the concept of the construction project team is moving from temporary to virtually
permanent team (Vrijhoef and Voordijk, 2004). Sharing knowledge among project
participants about the project and your partner’s businesses, will not only bring new
culture within the industry but will also bring benefits which will be enjoyed by
everybody within an integrated supply chain (Khalfan et al., 2005). They concluded that
effective knowledge sharing and improved mechanisms for KM across the construction
supply chain, offer the supply chain participants, a mechanism to improve their
performance through integrating construction supply chain, and added advantage to be
ahead of their competitors. The trend of people coming together, working for a number of
years and then dispersing is now out of fashion, since the competition in the construction
market is moving from firm level competition to supply chain level competition (Li et al.,
2007a). The changing role of the different participants within a construction supply chain
has resulted in the greater importance of gathering, storing and making strategic use of
project, supplier and market knowledge. DTI Report (2003) highlighted that the selection
of preferred suppliers in a supply chain is vital in order to get detailed information about
them and their businesses, for example, knowledge about:

- all potential first tier suppliers operating in the market and their capabilities
- suppliers that are being currently used
- whether any identified preferred suppliers are subsidiaries of
  competing organisations
- if the suppliers have any preferred arrangements with any competitors
- the extent to which they match the requirements of the client’s organisation in
terms of size, capacity, geographic coverage, relevant experience, management
organisation, cultural fit, quality, health and safety and environmental systems,
performance levels, etc.
- the structure of the marketplace and the extent of competition
- the nature of the supply chain, how many parties there are and where the power lies
- which second and third tier companies are used by first tier suppliers and whether
  it would be feasible and sensible for production/commercial reasons to open up
  relationships directly with these lower tiers
- the quality of the products/services – their detailed specifications for production and
  assembly and the upkeep of these specifications
- future anticipated changes in the supply chain members and the market-place
- competitive price levels; with respect to this point, it could be necessary to
  benchmark these levels with companies outside of the construction sector or even
  with another construction company that is not a direct competitor
- the client organisation’s forward order book, i.e., clients sharing the total spend
  profile with their supply chain partners.

Once these specialised knowledge have been gathered by all the participants involved
within a supply chain on a specific project, which can be achieved through the use of
questionnaires, holding meetings with suppliers and market research, it must be kept up
to date and made constantly available to all supply chain participants and project
personnel involved in selecting companies with whom they wish to work. Thus the core
of any KM initiative is to provide an environment conducive to create, develop and
nurture relationships between people, both by facilitating an environment that encourages knowledge creation and sharing it by providing adequate mechanism to capture, store and share the knowledge (Dawson, 2000). The sharing of such knowledge around the business is essential for working effectively with other supply chain participants in a more integrated manner. If supply chain integration is to achieve, it is also essential to form much closer relationships and build better knowledge of suppliers’ capabilities. Organisations increasingly rely on the networking of resources and competencies (Scarso and Bolisani, 2008). Quintas (2005) highlighted that knowledge is often created within Communities of Practices (CoPs) who share experiences and understanding that are transferable to those outside the community. Building networks and partnerships can act as source of generating information flow and knowledge and can help in promoting a strong degree of organisation integration, social capital, shared cultural values and a common vision.

2.4 Industry practices

As construction clients became more aware of better services, KM has increasingly become more important for construction organisations to integrate themselves into effective construction supply chains to stay competitive. Sheehan et al. (2005) stressed on better methods of managing organisational knowledge as the fundamentals for future survival and success. This section illustrates one of the industry practices observed during a case in which KM was implemented by a particular public sector client, through CoPs. CoPs are communities comprising of a group of individuals or teams that have a long history of collaborating together to develop into a cohesive community through shared understanding (Lindkvist, 2005). Wenger (1999) classified CoPs as the informal network of individuals who identify common problems, explore common solutions, share good practices and ideas around a specific area of knowledge. CoPs bring together a collaborative group of people willing and dedicated to sharing and developing knowledge. Table 2 below shows typical examples of how CoPs in the construction industry may improve construction supply chain through effective KM activities.

Table 2 Community of practice KM activities

<table>
<thead>
<tr>
<th>KM activities</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem solving</td>
<td>‘Can we work on this design and brainstorm some ideas; I’m stuck.’</td>
</tr>
<tr>
<td>Requests for information</td>
<td>‘Do you have information about the new regulations?’</td>
</tr>
<tr>
<td>Seeking experience</td>
<td>‘Has anyone worked on a similar project with similar situations’</td>
</tr>
<tr>
<td>Reusing assets</td>
<td>‘I have a project proposal, which I wrote for a client last year. I can send it to you and you can easily tweak it for your new client.’</td>
</tr>
<tr>
<td>Coordination and synergy</td>
<td>‘Can we work together to bid for this contract?’</td>
</tr>
<tr>
<td>Discussing developments</td>
<td>‘What do you think of the new project financing system?’ Does it really help?</td>
</tr>
<tr>
<td>Project documentation</td>
<td>‘We have faced this problem five times now. Let us write it down once and for all.’</td>
</tr>
<tr>
<td>Visits</td>
<td>‘Can we come and see what you are doing at your site? We have similar problems and/or requirements on our new project.’</td>
</tr>
<tr>
<td>Mapping knowledge and identifying gaps</td>
<td>‘Who knows what?’ ‘What are we missing?’ ‘Which other organisations should we contact?’</td>
</tr>
</tbody>
</table>

Source: Adapted from Wenger (2007)
3 Research methodology

The main aim of the research was to establish how KM within the construction industry can be applied to integrate the supply chain to ensure better quality whilst still supporting the initiatives of government and clients, aimed at increasing the competitiveness of the construction sector. The project conducted extensive field research and continuously reviewed academic, industrial and web-based literature to maintain an awareness of current developments. The project investigated changes in the quality of services in response to clients’ innovative procurement and KM initiatives. For this purpose a case study approach supplemented with semi-structured interviews was adopted. The advantage of the case study is that it can ‘close in’ on real-life situations and test views directly in relation to phenomena as they unfold in practice (Campbell, 1975). The case study approach followed the protocol developed by Stake (1995) and Yin (2002). The research used multiple methods to collect qualitative and quantitative data. Ragin (1992) went on to explain that criticising single-case studies for being inferior to multiple case studies is misguided, because even single-case studies are multiple in most research efforts because ideas and evidence may be linked in many different ways. The case study presented here is part of a research project, called, Supply Chain Integration within Construction, funded by EPSRC through IMRC funding Basic quantitative data and company documentation were used to provide research context while qualitative data, collected in the form of a number of unstructured interviews, sought to understand how KM was implemented to achieve integration by different supply chain partners. The case study attempted to uncover the perceptions of firms within the construction industry with regard to the existing KM they currently undertake. In order to validate the findings, the research involved multiple visits to client organisation and at least three interviews with managing directors. The main author conducted 15 interviews with senior management within the client organisation and their supply chain partners for this case study.

4 Case study

The case study was done with a public sector client, a local council, having a portfolio to deliver new and/or refurbished public facilities to the residents in North West of England. The projects included refurbishment of social housing stock, building primary and secondary schools through its in-house development team which acted as client by developing the specifications and allocating budget for different facilities. For this client-led innovative procurement of developing educational infrastructures, the council developed a framework agreement to construct primary schools (in first phase) with costs ranging £500,000 to £5 m. The council appointed three constructor partners initially for three years followed by an extension of two years in 2004. The core values of the framework agreement, for example, trust; honesty; openness; commitment; cooperation; and respect, based on the partnering concept, formed a virtual CoP between client and all other participants.

Case study data was collected through semi-structured interviews with managing directors and other staff members of each organisation involved in the supply chain. Interviews lasted for about an hour. Ever since the appointment, some projects have already been delivered, some recently started, and some are in the early stages of design.
The framework had a special focus on KM to improve the construction supply chain. The council’s vision that the framework agreement will deliver good quality school buildings is already being realised which has lead to, greater inclusion within the community; better safety and environmental performance; better educational results; and reduced costs by addressing whole life cycle costing at the inception of the projects.

Some of the major benefits that will be achieved by adopting the KM across the supply chain during construction of primary schools were identified as:

- overall improved cooperation between chain partners
- improved design as well as information management
- more real time co-planning and implementation
- improved delivery with greater quality
- greater certainty about cost and better whole life cycle costing
- building of trust and relationships
- bringing all ‘project knowledge’ together at the inception of a project.

Despite the absence of formal collaboration agreements between the three main contractors and their supply chain partners, team members got involved in these groups of CoP to capture and share their expertise and knowledge in their respective areas to add value to the project. As mentioned earlier, the case study about KM based CoP, described above, is a by-product of a bigger case study of supply chain management in our research centre.

5 Discussions and analysis

As part of the KM based framework agreement with the client, all three main contractors had to integrate their first tier supply chain, including the design team and M&E contractors. They all engaged with the client to develop the plans for the primary school development, sharing their knowledge and expertise, new knowledge for the specific project was also created. In addition, the introduction of a post-construction snag period (normally 12 months) would reduce the complaints from the end users (heads and building in-charge of the schools), resulting in much quicker responses and solutions to any problems occurring in the school building. This was due to knowledge retained by introducing snag period while the same contractor is still working with the client on other projects. This client-driven initiative is bringing all the parties involved into a community resulting in sharing of knowledge and experiences. Different mechanisms are used for KM including project meetings and special interest groups coordinated by the client in addition to the project intranet and formal meeting for each project. This level of coordination is unprecedented within the construction industry and resulted in clear construction supply chain integration as well as client benefits from:

- representatives of all three contractors sitting down together and agreeing on choice of standardised material, e.g., windows, doors, which resulted demand integration across the chain with scale economy
• architects reporting to different contracting organisations working together to learn from each others’ designs, hence high-quality design with better constructability was achieved
• learning from one project within the framework is documented and carried forward to new projects by capturing the experiences of the people involved; and the knowledge was transferred to other projects
• using special interest groups to find suppliers of material. This avoids duplication of effort by the three main contractors. It led to supply integration across the chain with big procumbent discount
• use of project intranet and e-mail facilities in addition to above, in order to support the knowledge capture, sharing, and reuse.

Knowledge captured and shared is both tacit and explicit. Explicit are the obvious ones in which the contact names and/or details of suppliers are provided by main contractors. Tacit would be when they start sharing their experience and knowledge of a process of constructing something which may have given them a competitive advantage within a traditional form of contacts and relationships. For example, the material specialist group is investigating the quality of different products and also working towards aggregating the demand. At the same time, they aim to reduce the number of suppliers for each product and ultimately to have a single preferred supplier (with an aim to have a shorter and integrated supply chain). At the same time, they are looking into standardised material, e.g., standard door and windows and also incorporating these standardisations within the design and specifications. Contractor personnel in the material specialist group have been able to draw on their previous experience and introduced known suppliers to the client. These standardisations will also be used in subsequent framework projects with nominated suppliers. The description presented above concerns KM among different supply chain participants who are working on different projects under different contractors and have no contractual relationship with each other. Such KM especially knowledge sharing was non-existent within the public sector framework agreements and other construction contracts where different main contractors (and their supply chain participants), working for the same local authority, would previously have been reluctant to share knowledge in case of putting their competitive advantage at risk.

Another important question is: Is quality improving by application of KM across the supply chain? In the case study concerned, the local authority has developed Key Performance Indicators (KPIs) to measure the performance of the contractors and their supply chains. The data gathered through KPIs shows the improvements in a range of measures, including satisfaction of the client through KM based construction supply chain (Khalfan and McDermott, 2007). Sharing knowledge about suppliers and subcontractors, as well as methods of installation and construction has resulted in improved quality, not only in terms of getting better products from suppliers, but also in terms of labour productivity, better constructed facility and value for money for the client. The above mentioned strategy not only helps client and involved parties to capture and share knowledge, but is also extremely beneficial for the whole supply chain especially if involved in repeat type of work, i.e., constructing primary schools. The integrated supply chains can use the lessons learnt from one project to another captured though CoPs resulting into savings in terms of time and cost, reduction in waste, more effective planning and scheduling on site and more efficient resource management.
6 Summary and conclusion

This paper has explored the role and method of KM to achieve an integrated and effective supply chain through literature review, theory analysis and a case study. The paper started with defining the concept of supply chain management within the construction industry as well as KM across construction supply chain. The CoP concept with focus on KM was only observed in one of the four case studies conducted; therefore, the other three case studies and their findings were out of the scope of this paper. The later part of the paper presented a case study within which CoP have been identified as an effective way of managing organisational knowledge and integrate construction supply chain.

The case study described a client-driven initiative in the construction industry where three subcontractors and their supply chains have become a community of practice, through KM to facilitate supply chain integration and cooperation, hence delivering better value to the client. The three main contractors involved themselves voluntarily in the whole process of capturing and sharing both tacit and explicit knowledge with their competitors in the region. The incentive of participation in KM is identified by the continuous work and opportunities for future work with the same client for at least five years. The process has been a valuable learning experience and lessons learnt have resulted in achieving improvement in Key Performance Indicators and better client satisfaction. The adoption of KM has improved the integration of the specific construction supply chain and facilitated the development of a community of practice focused on helping the client to fulfil their aims related to regeneration and sustainable communities (Khalfan and McDermott, 2006; 2007). The main contribution of the paper is to identify and highlight the applicability of KM to achieve construction supply chain integration to illustrate how this can be implemented using toolkits such as CoP’s to overcome organisational barriers and deliver benefits to clients.

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