FINDINGS FROM PRELIMINARY CASE STUDIES ON KNOWLEDGE FLOW IN AEROSPACE AND CONSTRUCTION SUPPLY CHAINS

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A critical issue in supply chain management (SCM) is the effective management of knowledge through the whole project lifecycle. Firms in both the aerospace and construction industries face considerable challenges to manage project knowledge effectively in their supply chains (SCs). With the high level of outsourcing in design and manufacturing, the effective use of project knowledge across the aerospace SC is acknowledged to be crucial to the success of any project. Similarly, the construction industry has a very fragmented SC and the effective use of knowledge across the SC is a big challenge for all actors in construction SCs. This research aims to define the key issues of SCM in the two industries and clarifies the gaps and bottlenecks in the knowledge flow through the SCs. For this purpose, the preliminary findings of case studies in the construction and aerospace sectors are presented in this paper. The main differences between the aerospace and the construction SCs are discussed. The key problems in SCM and knowledge management (KM) practices in these industries are clarified. The case study method adopted to investigate knowledge flow in SCs is described. Finally, the paper concludes that the findings of these case studies will be used to enable the SCs to transform into knowledge chains.

Keywords: supply chain management, knowledge flow, knowledge management, aerospace.

INTRODUCTION

Knowledge Management (KM) deals with the organizational optimization of knowledge to achieve improved performance, increased value, competitive advantage, and return on investment by integrating various tools, processes, and methods in the organizational workflow (Skyrme and Amidon 1997; Siemieniuch and Sinclair 1999). NASA briefly defines KM as "getting the right information to the right people at the right time, and helping people create knowledge and share and act upon information in ways that will measurably improve the performance of an organization and its partners" (Murphy and Holm 2008). This definition particularly differentiates from the other KM definitions with its emphasis on the "partners of NASA". The integration of knowledge, information and materials flow between the client, and supply chain (SC) actors defines the concept of supply chain management (SCM) (Samaranyake 2005).

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Today, knowledge is regarded as the most important resource in the SCs. Failure to transfer knowledge within organizations or along the complexities of SCs leads to wasting time and money; reinventing wheel for each project and impairs project performance (Koh and Gunasekaran 2006). Moreover, transfer of knowledge does not always mean the diffusion and internalization of knowledge in the SCs. The diffusion of knowledge through SCs depends on the KM abilities of the organizations in the SC. The premise in this research is that, KM principles adopted in the SC will support the main objectives of SCM and create innovative environment for knowledge cultivation, transfer and diffusion during project lifecycle. Considering the social and technical perspectives, the integration of KM practices in the SCs, can help to create collaborative knowledge sharing within the SCs, increase quality and lower costs. In the following section the current state of the two industry SCs are briefly discussed.

Construction supply chains

SCM in construction industry includes the coordination of principal contractors, subcontractors, suppliers, and distributors as well as managing process flow, knowledge flow, financial flow, materials flow, activities, tasks and processes between different actors of the SC. The network of suppliers in the construction sector can be extremely complex. Generally on a larger projects, the number of suppliers can be many hundreds (Dainty *et al.* 2001). A construction project includes various processes through the project lifecycle as procurement, planning, design, manufacture, construction, and facility management (Ireland 2004).

A construction SC is characterized by its generally unique product in every project, and repeated reconfiguration of SC for each project. This creates instability and fragmentation. Therefore, construction projects are treated as a series of fragmented operations without focus on long-term collaborative success (Vrijhoef and Koskela 2000; Briscoe and Dainty 2005). Besides this, the industry is mainly based on price competition and organizational contractual arrangements depending on the complexity of projects (Saad *et al.* 2002). The other considerable short-comings in the construction SCs are; inadequate co-ordination, communication and integration; lack of long term relationships between main contractors and key suppliers; lack of client focus; lack of process innovation; inadequate ICT skills in the SCs; lack of trust based culture; perceived low productivity; and cost and time overruns (Briscoe *et al.* 2001; Love *et al.* 2005; Konukcu *et al.* 2008; Tucket *et al.* 2001).

In construction SCs, where there is huge knowledge flow between the contractor, subcontractors, suppliers and distributors; cross-discipline coordination and knowledge exchange are crucial for the multidisciplinary collaboration (Aouad *et al.* 2002). However, creating collaborative working within this variable and complex SC context can be problematic. For effective SCM, all elements of the SC must be connected to enable the flow of knowledge (Desauza *et al.* 2003). This creates heavy reliance on KM to coordinate the whole SC (Tucker *et al.* 2001). As a result, the effective flow of knowledge through SC is considered as highly critical.

Aerospace supply chains

Aerospace SCs are characterized by variety of systems and parts that make up a high technology end product. The design of aerospace systems deals with complexity, traceability, maturity of knowledge, awareness of the status of information, trust in knowledge and interaction between experts (Boy and Barnard 2005). Aerospace systems are increasingly challenging to manage, and system interactions are growing more complex (Jafari *et al.* 2007).

The aerospace industry is characterized by severe competition and increasing outsourcing of high-technology elements (Bales *et al.* 2004). Globalization hugely affected the industry and in the last years firms are integrated into few large groups each trying to deal with the increasingly higher technological, financial and market barriers (Rose-Anderssen *et al.* 2009). Harsh competition, increased need to provide more innovation, and the need to minimize costs have changed the structure of the industry (Fine 1998). This led to high level of outsourcing in design and manufacture, and replacement of local western suppliers by low-cost country suppliers in the global market (Rose-Anderssen *et al.* 2009). Consequently, firms have concentred more on the core competencies of design, assembling and marketing (Jafari *et al.* 2007). Also, aerospace firms have to comply with strict rules and regulations established by the certification authorities and the certification process might consume more time than inventing a new product (Brusoni and Prencipe 2001; Voordijk and Meijboom 2005).

A typical aerospace project is long in duration and includes processes as specification and requirements definition, conceptual and detailed design, manufacture, assemble, test and certificate (Fan *et al.* 2000). The creation of knowledge during the project lifecycle is incremental. Owing large amount of knowledge and intellectual capital inside the aerospace industry, firms now face considerable pressure to improve co-ordination and flow of knowledge in their SCs (Tabibzadeh and Wireman 2003; Jafari *et al.* 2007). Particularly, with the high level of outsourcing, the aerospace industry is in a position to manage knowledge dispersed across several organizational units and geographically dispersed organizations around the globe (Meijboom and Vos 1997; Fan *et al.* 2000). Therefore, effective KM in aerospace SCs is considered as highly critical.

RESEARCH METHOD

This paper presents the preliminary findings of case studies held in aerospace and construction industries. Case study research is adopted since it can provide deeper investigation of the particular issues within the research subject (Fellows and Liu, 2003; Yin, 2003). For data collection, interviews were adopted due to the need for rich data that could facilitate the investigation of the SC and generation of the basis for effective knowledge chain framework. As such the theoretical implications of the research have served as a foundation for interviews conducted with large/mid scale aerospace and large scale construction companies. These industries were selected for comparison on the basis that they are different and they can learn from each other.

In the first stage of the case study, structured interviews were conducted to understand the general SC issues of the industries. Following these interviews, recently completed projects were selected. Another set of interviews with SC actors were constructed to investigate the chronological descriptions of the project knowledge shared through the SC. This involved the investigation of the knowledge flow and associated issues in detail. Through this work, an in-depth case history of project KM in the SC was obtained. In this paper, the results of the first stage of the case studies are presented.

PRELIMINARY RESEARCH FINDINGS

For this preliminary work, four structured interviews based on twenty-two questions were conducted with the SC managers for each industry. The questions were grouped under the themes as SCM organization; supplier selection criteria; SCM priorities; SCM relationships; knowledge exchange and collaboration; innovation, sustainability

and lean SC practices; and plans and thoughts for the future of SCs. The details of the interviewees and the findings are presented in Table 1, Table 2 and Table 3.

DISCUSSION ON FINDINGS

Aerospace and construction sectors have similarities in the project life cycle, both deal with procurement, planning, conceptual/preliminary design, detailed design and a production process. The production of aerospace industry comes through the manufacture and assemble process whereas in construction it comes through, manufacture and construction processes. Both industries provide maintenance to the end product. Because of these similarities in the project life cycle, both sector SCs deals with the coordination of firms from different backgrounds working together throughout the project. As observed from the case study and literature review, one of the main difference is aerospace projects are generally longer in duration and needs the implementation of very old and new technologies together which adds to much complexity to the project life cycle whereas construction projects are generally one of a kind and deals with the reconfiguration of the SC for each project. In both industries organizations have annual reviews on the SCs and have some specific criteria to select a supplier or to keep a supplier in their SC. In the aerospace industry, all four companies defined the main criteria as performance, quality and delivery whereas in construction, the main criteria was defined as performance, health and safety and cost. In the aerospace industry, the priority for the SCM is primarily quality, delivery, performance and then cost. However in construction, there is focus on customer satisfaction and cost mainly. This was a remarkable outcome which mainly tells about the SCM approach of the industries. Construction industry is still based on price competition, and this may come through the clients' cost based approach particularly in tendering.

Both industries benefit from old and mature relationships, however in the aerospace industry firms are open to new suppliers in material or high tech production areas such as rapid prototyping or electronics. They defined these areas as very quickly changing and potential source of innovation and cost reduction. However, because the cost of entity to the sector is high, aerospace SC is defined as composed of mature relationships. In construction, there is a tendency to have old relationships however currently construction SC composed of a combination of old and new suppliers in general.

Table 1: Summary of Interviews

Role	Type of Company	Years in the Company	Years in industry
Interview 1: Supply Chain Manager	Large Scale Aerospace (UK)	6	22
Interview 2: Supplier Development Manager	Large Scale Aerospace (Multi-nation)	5	17
Interview 3: Supply Chain Manager	Medium Scale Aerospace(UK)	3	25
Interview 4: Supply Chain Manager	Medium Scale Aerospace(UK)	6	20
Interview 5: Procurement Manager	Large Scale Construction(UK)	25	25
Interview 6: Supply Chain Manager	Large Scale Construction(UK)	7	20
Interview 7: Procurement Manager	Large Scale Construction(UK)	12	20
Interview 8: Supply Chain Development	Large Scale Construction(UK)	25	25

Table 2: Aerospace Industry Preliminary Survey Findings

Questions	Company A	Company B	Company C	Company D
1.SCM Organization	1.SC Mainly Based in the UK-1225 Suppliers-Annual Review of SC.	1.SC all over the world-200 Suppliers based in the UK-Monthly and Annual Review of SC	1.SC Mainly Based in the UK-300 Suppliers-Annual Review of SC.	1.SC Mainly Based in the UK-230 Suppliers-Monthly Review of SC.
2.Supplier selection criteria	2.Performance-Quality-Delivery- Financial Stability-Reference-Industry Standards	2.Performance-Quality-Delivery-Financial Stability-References-Total Cost of Acquisition-Q. Standards	2.Performance-Quality-Delivery-Financial Stability-References	2.Performance-Quality-Delivery-Financial Stability-References
3.SCM Priority	3.High quality-Delivery-Cost	3.High Quality-On time delivery-Increased Customer Satisfaction-Cost-Working Capital	3.Working Capital-Cost-Delivery-Quality	3.On time delivery-Quality-Approach on Returns and Defects-Response to Queries-Cost
4.SCM Relationships	4.Mature Relationships-No tendency for new suppliers-Open to new ones in manufacturing and instrumentation -Aim to reduce the number of suppliers-Long project durations, lack of long term active relationships-Open relationship with suppliers-Developed Category Management and Supplier Engagement Programme-Enrolled in SC21	4.Mature Relationships-Tendency to build longer term relationships with Speciality suppliers-Aim to reduce the number of suppliers-Communication problems in multinational projects-Blaming Culture when a problem occurs-Being key player in the world, bossy approach-Enrolled in SCREA, SC21	4.Old Relationships-Open to new ones in material suppliers-Aim to reduce number of suppliers Lack of SC Flexibility-Generally trust based approach to suppliers-Reliability issues with Material and Heat Treatment Suppliers-Used to have SC events, stopped after recession-Enrolled in SC21	4.Old relationships-Open to new relationships in high tech suppliers-Inadequate communication with small companies due to their lack of organizational skills as risk management, corporate culture and skilful employees-Enrolled in programmes as SC21, SC Groups
5.Knowledge exchange (KE) and Collaboration	5. KE by emails, phone, face to face meetings, post-Loss of knowledge due to employee turnover in long project durations-Problems in translation of design knowledge to manufacturing- Difficulties in finding firms and people who can deal with very old and new technology knowledge together.	5. KE by emails, face to face meetings, video calls- Lack of knowledge sharing culture-Blame Culture impedes knowledge sharing-No Lessons learned-Same design tools in all designers- Issues due to different cultures and language-No encouragement to use the knowledge transfer database during projects, limited and inconsistent knowledge.	5. KE by emails, phone calls, face to face meetings, rarely use video/audio-Lack of collaboration tool-Lack of common design/modelling tools and process-Lack of collaborative working culture-Better collaboration with old suppliers.	5. KE by phone calls, face to face meetings-Organizing steering group meetings with main SC actors to encourage knowledge sharing- Early engagement with suppliers in all levels-managerial-engineering-manufacturing to encourage knowledge sharing- Web based real time system to flow down purchase orders
6.Innovation, Sustainability and Lean SC practices	6.The best time for innovation is in conceptual design-Early involvement of supplier adds value to innovation-Sustainability in SC is a big problem because of very long project times-To be lean is SC strategy-Developed "Process Excellence" programme for leaner chains – Reduced the number of suppliers-Using Integrator Companies for leaner chain-Outsource in Europe	6.Innovation is defined to come through more collaboration with customer/ Strategy is being flexible to make changes in design/ Main innovation is expected in products/ Lean is a developing area/ Constant drive to decrease number of supplier/ Tendency to decrease volume of employees dealing with suppliers/ Outsource in Asia/	6. Need to be highly flexible and innovative in process- Lean manufacturing became key issue after recession- Huge change in customer orders, big players do not want stock-Sustainability is an issue; working with small companies, lots has disappeared after recession-Outsource in Far Eastand East Europe.	6.Better transformation of customer requirements to design requirements and early collaboration with the suppliers brings innovation-Main focus on product innovation-Globalization changed SC structure, made fragmented-Outsource in Far East.
Plans and Thoughts for the Future of SC	7.Robust and Leaner SC-Further Development in SC Relationship Programmes-Seeking ways to transfer the design knowledge to manufacturing with more accuracy.	7.Geting the most benefit from the national SC schemes as SC21(UK), SCREA, SPACE(French)-Need cultural changes and ICT solutions for effective knowledge transfer-Lean approach from day one in SC	7.SC needs to recognize lean and value approach- Expecting more knowledge on workload from customers. Expecting better knowledge transfer from customers-No more delays	7.Trying to position well to prepare the company for harsher business in future. Financial stability is becoming an important SC priority-Longer term relationships for sustainable SC.

Table 3: Construction Industry Preliminary Survey Findings

QUESTIONS	Company E (2 interviews)	Company F (2 interviews)
1.SCM Organization	1.SC Mainly Based in the UK-600 Suppliers-Annual Review of SC	1.SC Mainly Based in the UK-330 Suppliers-Annual Review/ 3months review of SC
2.Supplier Selection Criteria	2.Performance-HealthandSafety-Cost-Ethics- Outlook-Openness	2.Performance-HealthandSafety-Financial Stability-Cost-Collaboration.
3.SCM Priority	3.Cost and Client satisfaction	3. Consistency, Client satisfaction, quality, cost
4.SC Relationships	4. Combination of old and new relationships, mainly old-Extremely fragmented SC- Communication issues in SC especially with small firms w/o organizational skills-Trust based relationships, on time payment, fair treatment-Organize Supplier Days in every 2 years-Tend to use Supplier Protocols rather than partnerships	4.Mainly old relationships, open to new actors-Aim to be Best Friends with SC-Trying to build collaborative relationships from Design Stage with suppliers and subcontractors-Organizational resistance to change in SC-Client's cost oriented approach destroys relationships in SC-Developed programmes as Building Constructive Relationships, Early notification of Project Scheme, Preferred Supplier Agreements.
5.Knowledge exchange and Collaboration	5.Knowledge exchange through face to face meetings, emails, phone-Ineffective usage of the IT tool to share project knowledge/ Not very user friendly-Lack of ICT skills in suppliers-Lack of an established KM strategy-Lack of collaboration with Suppliers and subcontractors during tendering-No encouragement on KM- Suffering from knowledge loss after each project- Lack of early collaboration between the suppliers and designers	5. Knowledge exchange through face to face meetings, emails, audio-video conferences – Issues in knowledge sharing in design chain-Arranging informal/lessons learned meetings to encourage knowledge sharing in SC-Using IT tool for project knowledge sharing, found to be a good tool- Signing agreements with suppliers to keep innovative knowledge confidential-Lack of common design tools
6.Innovation,Sustainability and Lean SC practices	6.Lack of innovation coming from designers-No outsourcing-No effect of Globalization-No lean application so far -No activities on sustainable procurement or sustainable processes.	6.Innovation is defined to come through collaboration between designers, subcontractors and suppliers-Trying to become leaner by reducing the number of firms in SC-Outsourcing in Far East for material suppliers-Trying to reduce waste for sustainable SC.
7.Plans and Thoughts for the Future of SC	7.Needs a well established KM approach in SC-Integrating designer with subcontractor and supplier in design process- Encouraging knowledge sharing in SC- Minimizing faults on site coming from poor documentation control / Benefiting from ICT tools-Leaner construction process and IPD.	7.Needs to improve trust, and long way to improve knowledge sharing and collaboration between the actors of the SC.

The aerospace industry seems to benefit highly from national SCM programmes which helped them to develop common values and created awareness in many SCM practices. These differences have fundamental implications for the way that SCM is understood and implemented in the two sectors. All of the firms interviewed were enrolled in SC21, a UK based SCM improvement programme which is led by Society of British Aerospace Companies (SBAC). Through this programme, with the support of SBAC, the enrolled companies invite the main actors in their SC to enrol in this programme and apply the same standards and performance metrics in their processes. SC21 and the similar SCM programmes had a great impact in the aerospace industry in terms of standardization, improved quality, encouragement to change and awareness for SC development. In the construction industry, there is not a national programme to improve SCs. However, one of the interviewed companies developed special programmes to improve SC relations, to know and understand their suppliers better. Another company was making supplier days every two years which is a quite weak approach when it is compared to the similar company in the same sector. This large construction company relies on fair treatment and on time payments to keep good relationships with suppliers mainly.

As reviewed both in the literature review and the case studies, aerospace companies have undergone extensive global competitive pressures and restructured by outsourcing design and manufacture in the recent years. All aerospace companies interviewed have outsourced in Far East, Asia, and Europe. This gave them the opportunity to minimize costs and concentrate more on the core competencies of design, assembling and marketing. Three of the aerospace companies interviewed put "becoming leaner" as a SC strategy and there is a tendency to create lean SC from the day one of the projects. In contrast, construction SCs did not have that much challenge from globalization. Instead, the construction industry has experienced fragmentation and remained highly localized. Although there is a tendency in the construction companies to reduce the number of suppliers, and minimize waste, they still lag behind the aerospace industry in terms of implementing lean processes.

In the aerospace industry the project durations can be very long and there are always challenging projects as updating or maintaining a very old product after a long duration. In these cases, companies have difficulties finding the same suppliers or to find new suppliers who can handle both technologies together. It is observed that the large aerospace companies suffers hugely from knowledge loss in between similar projects. Even the company leading the private aerospace industry has issues to keep project knowledge and benefit from it in the future. The interviewee explained that in recent years, they standardized the design process and tools, however when there is not a culture which supports effective knowledge sharing, the set goals are never achieved. Both industries suffer from the lack of effective knowledge sharing tools and methods, and lack of corporate knowledge sharing culture; and none of these industries have a mature KM approach. Both have problems in knowledge flow starting from design to the delivery of the end product. In the aerospace industry, the translation of design knowledge to manufacturing is still an issue. Similarly in construction, the translation of design knowledge to construction is an issue. In both industries, this is mainly due to the lack of effective collaboration tools, lack of a knowledge sharing culture, lack of common design tools, and inadequate collaboration between designers, subcontractors, and suppliers for both sectors.

The aerospace industry interviewees explained that the source of innovation is defined to come through better collaboration with the client; better transformation of client

requirements to design requirements; and better collaboration with suppliers. The best time for innovation is defined as the conceptual design. Similarly in construction industry, the source of innovation is defined as the early collaboration of the design chain, subcontractor, and suppliers. In one construction company, the source of innovation is defined as designers. The construction industry interviewees had a quite different approach in innovation. One was more aware of the need for collaborative work and knowledge sharing for innovation, however the other was expecting innovation from only design, and ignoring the input of subcontractors and suppliers.

For the future of SCs, the aerospace industry interviewees explained that the issues related to lean and sustainability will be the main areas that they would like to develop in their firms. The importance of the SCM programmes for further development was highlighted for a better future. Also, effective KM will add value to all the firms in the SC. The construction industry interviewees mainly highlighted the need for improving knowledge sharing, transfer in between the design chain and the rest of the SC, it was also added that making KM as a strategy in the SCM will help to minimize faults, delays and will bring more innovation in construction industry.

CONCLUSION AND FUTURE RESEARCH

In this paper, key issues of SCM in aerospace and construction industries were discussed. These two industries were selected for comparison on the basis that they are very different and they can learn from each other. The preliminary findings of the field survey which consists of structured interviews conducted with large-mid scale aerospace and construction companies were presented. These interviews were aimed to collect data on general SCM and KM issues in the SCs. It is observed that although the processes in aerospace and construction SCs have similarities, the structure of the SCs have differences. Global competition has a great effect on the aerospace industry and caused the aerospace SCs to restructure by outsourcing to minimize costs. This made them concentrate more on their core competencies as design, assemble and marketing. As a result of this, they had the challenge to improve their SCs and became leaner. In contrast, construction SC is highly fragmented and is highly localized. In terms of KM both sectors suffer from ineffective project knowledge sharing, inadequate collaboration between design teams, subcontractors and suppliers. Aerospace industry has more standardized processes in the project lifecycle compared to construction industry however, when the technology and process is not supported by a corporate culture, the progress in KM is very limited. Both industries suffer from the lack knowledge sharing culture. In terms of supplier relationships, the aerospace industry is ahead of construction and the main reason for this is the national SC improvement programmes applied. This programmes brings standardization in performance, delivery, and helps to build up closer relationships in the SC. In the construction industry, there are also good SCM programmes applied by companies but these are limited and not standardized. Construction SCM priority is still mainly based on cost and client satisfaction while the aerospace industry mainly concentrates on performance, quality and cost. There is a tendency to build mature relationships in both industries.

Following the preliminary case studies, in the next stage of this research, interviews were conducted to investigate the chronological descriptions and issues of the project knowledge shared through the SC of a particular project. Through this work, an in-depth case analysis of the project KM across the SCs was obtained. Based on this, a framework will be established for transforming the construction SCs into knowledge

chains that promote knowledge diffusion across the SCs taking full cognisance of both the technical and social aspects of KM.

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