Chapter 15

Re-using knowledge and leveraging technology to reduce project duration, design and construction costs

Herbert Robinson and Chika E. Udeaja

1. Introduction

Construction is a vast industry accounting for a significant proportion of Gross Domestic Product and employing millions of people. The industry is well known for its products – buildings, roads, bridges, dams, and monuments requiring knowledge from specialists to meet the needs of diverse clients. Construction projects have a history of not delivering on time, budget and within the scope of the project. There are many reasons identified for poor performance such as inadequate communication between project teams, frequent design changes and constraints in knowledge re-use during project implementation. The lack of an effective knowledge management strategy has stifled the industry's ability to re-use knowledge and to leverage various technologies. This chapter focuses on knowledge re-use and leveraging technology in project processes to reduce project duration, design and construction costs. It starts with an overview of construction as a project-based industry, characterised by distinct processes and multi-disciplinary teams with different roles. The types of knowledge and knowledge management tools are discussed using examples from leading consulting practices and case studies to demonstrate the benefits in terms of reducing costs and time of construction projects.

2. Knowledge re-use in construction processes and projects

Construction is a project based activity, with interrelated processes from planning, design, construction to operation. Research conducted by den Hertog and Bilderbeek (1998) and Windrum et al (1997) identified design and other construction processes as knowledge-intensive service sectors. Quantity surveying firms as design economists offer a range of services as shown in Table 1 to reduce project duration, costs and to provide value for money to clients.

Table 1: Traditional and New Services offered by QS Firms

Traditional services: • Preparing tender documents (usually based on bills of quantities) • Examining tenders, appraisal and providing advice on selection • Valuing works for interim payments and certification • Measuring and valuing variations • Advising on anticipated final costs • Preparing and agreeing final accounts
New and emerging services • Procurement and project/construction management • Legal and contract services – contract documentation • Planning supervision • Taxation/capital allowance advice • Value and risk management • Asset and Facilities management • Construction product advice based on whole life cycle costing

- Management and business consultancy including corporate sustainability
- Sustainable design (energy and water efficiency), carbon planning and management
- Dispute resolution and claims management
- Technical advice on complex procurement systems such as PFI/PPP

Knowledge is at the core of quantity surveying activities and a significant proportion of knowledge relevant to other projects can be reused (Davies et al, 2007; Fong and Cao 2004). However for project knowledge to be reused, it must be captured in appropriate formats with a good understanding of the context to reduce project duration, design and construction costs. The types of reusable knowledge are related to the range of services in Table 1.

Key benefits in re-using knowledge include competitive advantage and improved relationship with clients leading to better results and the minimisation of waste. The emergence of the knowledge intensive organisations such as professional services firms in accounting, engineering, architecture, surveying, law and management consulting has seen intellectual capital (knowledge) replace physical capital. Chang and Birkett (2004) argued for a balanced between creativity and productivity in knowledge intensive organisations. However, specialist knowledge is 'lost from one project to the next stifling an organisation's ability to develop knowledge and generate new ideas' (Egbu & Botterill, 2002, p.129) necessary to reduce project duration, design and construction costs. There are many opportunities for improving productivity and creativity in project processes. A typical construction project cycle consists of stages from planning to maintenance. For example, the RIBA plan of work (RIBA, 2013) has eight stages (see Table 2).

Table 2: Example of a Construction Project Cycle (RIBA Plan of Work)

Project Cycle	**Stage**	**Sub Activities**	**Cost Activities**	**Examples of Tools Used**
Planning	**0**	Strategic definition	Feasibility studies Realistic first estimate	RIPAC, WINQS CostX
	1	Preparation and Brief	Preparation of estimates	RIPAC, WINQS CostX
Design	**2**	Concept design	Cost planning Cost limit Cost allocation	Project Management tools RIPAC, QSPlus CostX, BICS database
	3	Development design	Bill of quantities (BOQ) Detailed cost plan	RIPAC, Masterbill WINQS, QSPlus CostX
	4	Technical design	Schedule of materials Specification	RIPAC WINQS
	5	*Specialist design*	Cost analysis	RIPAC, WINQS
Construction	**6**	Construction	Valuation Cost control	RIPAC, ConQuest WINQS, Masterbill
Maintenance	**7**	Use and Aftercare	Final account	RIPAC Masterbill

The various activities are carried by specialist teams such as architects, engineers, quantity surveyors, town planners, developers, contractors and specialist trade or sub-contractors. Re-using project knowledge and leveraging some of the technologies identified in Table 2 can reduce project duration and save costs. However, this requires a knowledge strategy to overcome specific problems such as the temporary or one-off nature of construction projects' with teams often disbanded at the end of the project leading to 'discontinuities in knowledge reused within and between organisations' (Blayse and Manley, 2004).

3. Knowledge re-use in construction projects

Creativity can be nurtured and improvements realised in the construction process by interaction of various types of knowledge – explicit and tacit. Explicit knowledge can easily be processed by a computer, transmitted electronically, or stored in databases' (Nonaka and Takeuchi, 1995). Explicit knowledge is stored as written documents or procedures. This type of knowledge is codifiable, reusable and therefore easier to share. Examples of explicit knowledge in construction include design codes of practice, performance specifications, drawings in paper-based or electronic format, construction techniques, and materials testing procedures, design sketches and images, 3D models and construction textbooks (Egbu and Robinson, 2005). Tacit knowledge is described as being 'resident within the mind, understanding, perception and know-how of individuals' and includes 'skills, experiences, insight, intuition and judgement' (BSI, 2003). Examples of tacit knowledge include judgement on estimating and tendering skills acquired by quantity surveyors or estimators over time through hands-on experience for preparing bids for construction projects as a result of understanding tender markets, interaction with suppliers, various specialists and clients/ customers to develop project needs. This type of knowledge is experiential, judgmental, context-specific and therefore difficult to codify and share.

Reusing knowledge involves automating human and technical processes and/or creating a network of people involved in design and construction to minimize waste, prevent the duplication of effort, avoid the repetition of similar mistakes from past projects and improve efficiency (Kamara *et al.*, 2002, p.58). For example, 'reuse of knowledge gained via past experience can greatly reduce the time spent on problem solving and increase the quality of work' (Dave & Koskela, 2009, p.894). This creates a commercial advantage for a company as they become more efficient and produce a higher quality of work through the re-use of knowledge (Dent & Montague, 2004). A well-managed programme of 'knowledge re-using starts at the planning/tendering stage and continues after practical completion, to greatly enhance client satisfaction' (British Standards Institute, 2003b, p.6) and to reduce both capital and operational costs associated with maintenance. The increased likelihood of further commission through reappointment with the client, for example, can also reduce planning, design and construction costs.

4. Leveraging Knowledge Systems to Reduce Time and Costs

Various knowledge management tools have been in use over time to increase productivity and to foster creativity in the design and construction process. Take a simple example of the traditional method of drawing. This approach was very labour intensive and time-consuming as the process of making even minor changes to paper drawings was tedious, repetitive and costly. The introduction of CAD revolutionised the design process, reduced the time and cost associated with design, making changes to design as well as the incidents of defects during construction as a result of the early detection of conflicting design information in drawings. Arup Associates, one of the pioneers of CAD, had a separate system for project cost management (Oracle bases Project Control System -

PCS) using quantities manually determined from CAD drawings. The introduction of digitizers, helped in the transforming quantities, through manual takeoffs, or importing CAD drawings into the early cost estimating packages. Jeff Gerardi, the President of ProEst Estimating Software argued that performing 'takeoffs using electronic plans and a mouse is about 50% faster than manual takeoff methods, which is measurable efficiency gain that is easily converted to a cost savings'(Newsletters, 2013a). There are significant productivity increase using these methods as human error and inaccuracies are minimised.

Over the decades, there has been a rapid development in the use of knowledge systems to automate both the design, and estimating process from CAD to Building Information Modelling (BIM) or what is appropriately called Building Knowledge Modelling (BKM). By using BIM, all measurements are generated directly, and whenever there is a change in design, the measurements are automatically updated leading to greater accuracy in quantities and significant productivity increase. It is estimated that about 50-80% of time needed to create a cost estimate is spent on quantification. According to Revit 'by automating the tedious task of quantifying', BIM allow estimators "to use that time instead to focus on higher value project specific factors – identifying construction assemblies, generating pricing, factoring risks – that are essential for high quality estimates" (Autodesk, 2013a). Revit identified one customer with significant productivity gains experienced using Revit Architecture based on 20 completed projects – the firm had registered a productivity gain of 30% in design and documentation and a 50% drop in request for information during construction (Autodesk, 2013b). Applying these technologies would result in much earlier and accurate advice to meet clients' cost expectations. BIM, as an integrated design, cost and time management system has the potential to foster creativity, improve productivity of design, leading to a significant reduction in construction costs and time associated with delivering construction projects. BIM is discussed in extensively in Chapter 21.

There are many other good examples of reducing project duration, design and construction costs indirectly or directly through knowledge re-use by leveraging various technologies. Over a decade ago, Arup, a leading engineering consulting firm highlighted that feedback from their legal department shows that the single largest cause of loss of money within the firm was a failure to agree the appropriate contract terms up front. The knowledge manager explained that a knowledge management system such as the collation of a legal Intranet page pushed to the desktop at appropriate times in projects was an effective solution to the problem (Robinson et al, 2005). Other examples cited in Robinson *et al* (2005) include Texas Instruments who saved $500 million in the cost of building a new silicon wafer fabrication plant by disseminating best internal working practices to improve productivity in existing plants. Skandia AFS also reduced the time taken to open an office in a new country from seven years to seven months by identifying a standard set of techniques and tools, which could be implemented in any new office. Automatic identification technologies such as barcoding widely applied in manufacturing, retail, medicine and in the US construction industry offer cost savings through improved speed and accuracy of records. Use of bar coding for labelling materials and components as knowledge systems has reduced material wastage, theft from construction sites and other losses associated with poor tracking of supplies. A revolutionary technology developed called contour crafting has the ability to build a two-storey house in 24 hours (Weston, 2010). The robot "prints" buildings by squirting successive layers of concrete on top of one another to build floors, walls and roofs and can also integrate mechanical and electrical services within the structure.

Mohammed (2008) cited numerous examples of knowledge tools used earlier by leading design and construction firms. For example, in 1996 Atkins developed its first Intranet/Extranet and online

project management system ProNet as a central repository of company information and resources. The subsequent knowledge management system, called iProNet (Internet Project Network) developed in 1999 improved co-ordination from PFI/PPP projects by allowing 'virtual team members' to collaborate on projects in a protected environment, sharing folders and files, tracking activity with one third of users external to Atkins. Knowledge management in Arup can be traced back from the founder of the firm 60 years ago reflected in Ove Arup's key speech in 1942 '*The wealth of new knowledge, new materials, new processes'*. An earlier example is the Overguide, a directory of engineers with their experience, and a Skills Network. Arup had a variety of formal Project-based Information Systems for over 30 years including Ovabase, a project database and Autonomy with features such as information access technology, business intelligence, customer relationship management, compliance and litigation solutions all integrated in the intranet system.

The concept of knowledge sharing first became a group agenda in early 1990s when AMEC had over 20,000 employees, with more than 20,000 people in the associate company, SPIE S.A., in 700 locations around the world. The response was to deploy HummingBird Document Management System in 1996 supported by a KM system called ASK (AMEC's Shared Knowledge), which enabled users to access centres of excellence, profiles and communities of best practice. Capturing best practices from other parts of AMEC was crucial. A good example was Heathrow Terminal 5 (squeezed between Heathrow's busy runways, terminal buildings and one of the world's busiest motorways) where space was a challenge. There was not enough room for the workforce and materials. To address this challenge, AMEC brought the concept of modularisation from its oil and gas sector, where it was used for a number of years in producing offshore platforms.

Costain's Document Management launched in 2004, iCosNet was the main initiative designed by the company as the heart of the knowledge strategy. iCosNet had several key features such as Navigator engine allowing project managers to 'follow the job' through a series of charts, prompting the user to download standard forms and information - ensuring they are following Costain's international best practices at all times. For example, Photo Library provides an on–line access to photos of past and current projects, project collaboration tool allowed users to access and exchange information from anywhere in the world with a Supply Chain Management system for suppliers and sub-contractors.

These knowledge systems led to significant savings associated with construction projects. The examples also show that different tools are used depending on its added value to the organisation. However, for the next-generation knowledge tools, Anumba (2009) argued that the tools need to make seamless the linkage between knowledge capture/re-use and construction business processes. New technologies are sometimes seen as creating extra workload, as project documents are transformed into electronic form, and then uploaded to the extranet. The key to success of any knowledge system is not to create additional workload but to integrate knowledge capture activities for learning in daily job functions in normal working hours. The extranet can enable project documents to be tracked automatically with a clear audit trail of revisions and approvals to drawings and other project documents.

5. 4Projects Knowledge Solution

4Projects is a provider of collaborative web-based solutions for project management since 1997. The company started as a subsidiary of an international housing and development company, but subsequently became independent from the parent company and was later acquired by a US based firm (Newsletters, 2013b).

4Projects's on-line project collaboration platform to facilitate the management of knowledge in the form of drawings, specification and construction documents, for construction firms with multiple simultaneous projects to increase document and project control throughout the project lifecycle. According to Bob Humphreys, Vice President of Product Management, 4Projects 'allows your project teams to access and act upon a single set of construction documents and provides deep functionality and full audit trails' (Newsletters, 2013b). The Construction Manager (2013) added that 'on-line collaborative working is one tool that can drive down costs and improve process control'.

For example, 4Projects developed specific modules for discussion, query/action, team and organisation, work flow and approval process.

The **'Discussion'** module, similar to an online Communities of Practice, allow users to post topics for discussion, which can be open or restricted to a group of selected members within the project extranet. Recipients are notified of new discussion topics via email alert to debate issues of interest and to share tacit knowledge. Comments posted in the discussion forum are linked to items such as documents, drawings, photographs, queries and other material uploaded to the project extranet. A 'Search' function is provided for the users to search for discussion through keywords. The stored documents are searchable using the file name or keyword of the file description. Users can search and obtain a list of relevant documents or previous examples containing learning from other projects.

A **'Query/Action'** module also referred to as 'Task' module is available for users to request for information, ask questions or issue instructions relating to the execution of a project. The user can issue the query or request for information to a specific person or a selected group of people with the deadline. The status of a query is displayed to allow tracking of the progress:

a) Overdue; where the specified recipient does not give a reply on or before the deadline, or
b) Closed; where the 'issuer' of the query obtained the desired answer/reply from recipient, or
c) Open; where there is on-going correspondence between issuer and recipient on the query.

The **'Query/Action'** module can facilitate a more 'forceful' way of sharing knowledge, in contrast to the voluntary knowledge sharing in online communities of practice, as the identified source of knowledge is required explicitly to respond to the request within the deadline specified and the progress is traceable.

The **'Team and Organisation Directory'** is for storing key information on each organisation and individuals working on a project. It helps in locating a person's contact details. Adding a new 'field' like 'skills and expertise' for team members and then linking it to a cross project and cross organisation 'search module' can help in upgrading the module to a 'knowledge catalogue' to assist others to locate people with certain expertise.

The **'Workflow and Approval Process'** module provides an audit trail for all the items on the extranet. Documents can either be approved, rejected or under-review. This particular feature facilitates the peer-review process for documented learning and seek suggestions for improvement before knowledge is formally tagged for re-use as 'best practices' or 'lessons learned'.

In addition to the modules to facilitate document, communication and process controls, other functionalities have been added such as E-Forms, Milestone Management, Tender Management and

Contract Management. In 2010, 4Projects included a **Contract Manager Module** to reduce the 'administrative burden by automating processes, communication, reporting and notifications. The module will enable any type of contract to be incorporated into its collaboration platform from NEC, JCT, GC Works, PPC2000 to firms' bespoke contracts (Construction Manager, 2013).

6. Case Studies and Discussions

The entire database in 4Projects extranet for a project including all files, meta-data and audit data can be archived and re-accessed for future reference. Users can access the knowledge captured by the extranet modules and reapply it to other projects with adaptation. The case studies below are extracts from the 4 Projects' website.

6.1 Case Study on Leisure and Entertainment Sector

A leading organisation own and manage a network of over 2,000 branded pubs, bars, restaurants and leisure venues including some of the most popular entertainment facilities in the UK. A major challenge for the organisation was the sheer number of projects to be managed effectively in terms of reducing the delivery time, design and construction costs. A web-based solution (4Projects) was adopted to maximize the performance of the refurbishment programme and to develop a central knowledge base to manage multiple projects. 4Projects provided an interface for project members with an instant snapshot of the progress of all projects using a consistent format for sharing project files throughout the supply chain.

The company was able to rollout the web-based solution to thousands of users in a very short space of time as it was designed to be user-friendly. A number of features made the interface easier for construction workers such as the online versions of traditional drawing issue sheets. 4projects system provided a project team with a one-stop-shop for up-to-the-minute project information, resulting in significant savings in time, and allowing the team to keep to tight schedules. Little or no training was required to use the *point and click* menus and *hypertext links* to navigate project information and authorised users can add new projects in seconds. The online system had different components such as the *project scheduling and programme* component for managing developments, replacing the organisation's complex system of spreadsheets. The online management tool was used for collecting, viewing and reporting on the development status of projects within the estates portfolio. Individual project data is captured such as:

1. Project type (e.g., acquisition, conversion)
2. Associated project team e.g. architect, engineer, quantity surveyor etc
3. Proposed rollout programme based on dates (e.g., build start, build complete)

The *project cost monitoring* component was used for collecting, viewing and reporting on the financial aspects of managing the estates portfolio. Budgeted, forecast and actual costs can be assigned to each project. Traditionally both project scheduling/programme and project cost monitoring were managed in-house but changes in business practices combined with using web-based project solution meant it could be outsourced but still under the control of the organisation. Providing this data online through the web-based solution (4Projects) provided a secure way of accessing live and confidential project data in real time.

6.2 Case Study on Health Sector

The National Health Service in UK spends around £100 billion and employs about 1.2 million people (Storey et al, 2008). There are over 400 Healthcare Trusts whose principal aim is to provide local healthcare services through hospitals and GP surgeries across the UK. With the rapid changes in

the health sector there has been renewed emphasis on improving performance throughout the health sector particularly for capital projects. Several NHS Trusts led the way in adopting well proven project management solutions. The 4Projects extranet and tendering solutions, accessible 24hrs a day, enable sharing of critical business information in a secure environment. Some of the NHS Trusts that use the solution include:

- Wolverhampton NHS Trust
- Leeds Teaching Hospital NHS Trust
- North Glamorgan NHS Trust
- Portsmouth Hospitals NHS Trust
- Royal Orthopaedic Hospital NHS Trust
- Gwent NHS Trust

Portsmouth Hospitals NHS Trust was the first to discover the benefits of the 4Projects extranet on a PFI scheme that involves the redevelopment of Queen Alexandra Hospital site, with an estimated capital value of £170 million. Project information was shared between the client, funders, lawyers, designers and contractors. 4Projects enabled quick and effective communication between the consortia, project team and other staff involved in the project. Using 4Projects facilitated an instant viewing of the latest documentation and drawings in the project with a user-friendly interface. 4Projects was used by Leeds Teaching Hospital NHS Trust with two consortia reviewing tender documents and submitting bids. The result for bidders and advisers was increased efficiency, by accessing electronic documents in a Virtual Data Room from their offices throughout the UK or even overseas, as an alternative to physically visiting the Project Data Room at the Hospital to view paper documents.

North Glamorgan NHS Trust signed an Enterprise agreement allowing them to run unlimited projects using the extranet system. 4Projects has been set-up for the refurbishment programme at the Prince Charles Hospital and the new Acute Mental Illness Unit. Performance benefits delivered by using on-line collaboration system were substantial and far superior to project managing information by traditional paper methods. Medicor (a consortium comprising of Pearce Health, Parsons Brinkerhoff, MJN Colston, Davis Langdon & Everest, Integral and United Healthcare) adopted 4projects for a number of health schemes in the UK. A key objective for using 4Projects extranet was the use and re-use of standards, knowledge and best practices shared effectively throughout the consortia and supply chain.

6. Concluding Remarks

It is important for the knowledge re-use strategy to be aligned to important project objectives, supported by appropriate technologies with adequate measures to assess effectiveness to win support from top management and stakeholders involved in the project. Leveraging technologies can facilitate knowledge re-use and improve communication on projects as team members are always confident that they are working on the latest design, drawings or documents. The use of technologies cited in this chapter including 4Projects has resulted in significant time-savings in document transactions at bidding, tracking design changes and construction processes leading to reduction in project duration, design and construction costs.

There are different types of project benefits to be expected: both tangible and intangible during planning, design and construction changes which will all lead to creativity and productivity gains.

References

Anumba, C. J. (2009) 'Towards next-generation knowledge management systems for construction sector organisations', *Construction Innovation,* 9 (3), pp. 245-249 *Swetswise*. : http:/www.swetswise.com (Accessed: 5 Sept. 2009).

Autodesk (2013b) BIM's Return on Investment, http://www.autodesk.com/revit accessed 9/11/2013

Autodesk (2013a) BIM and Cost Estimating, http://www.autodesk.com/revit accessed 9/11/2013

Blayse, A. M. & Manley, K. (2004) 'Key influences on construction innovation', *Construction Innovation,* 4 (3), pp. 143-154 *Swetswise* [Online]. Available at: http:/www.swetswise.com (Accessed: 4 June 2009).

British Standards Institute (2003) *PD 7503: Introduction to Knowledge Management in Construction*. London: British Standards Institute.

Construction Manager (2013), www.construction-manager.co.uk/cpd-zone/cpd-building-platform-construction-efficiency accessed 9/11/2013

Chang, L & B. Birkett (2004). Managing intellectual capital in professional service firm: exploring the creativity-productivity paradox. *Management Accounting Research*, 15, 7-31.

Chen, L. & Mohamed, S. (2007) 'Impact of the internal business environment on Knowledge Management within construction organisations', *Construction Innovation,* 8 (1), pp. 61-81 *Swetswise* [Online]. Available at: http:/www.swetswise.com (Accessed: 6 June 2009).

Dave, B. & Koskela, L. (2009) 'Collaborative knowledge management - a construction case study', *Automation in Construction,* 18, pp. 894-902 *Swetswise* [Online]. http:/www.swetswise.com (Accessed: 4 June 2009).

Davis, R., Watson, P. & Man, C. L. (2007) 'Knowledge management for the quantity surveying profession', *E-learning and Knowledge Management,* [Online]. Available at: http://www.fig.net/pub/fig2007/papers/ts_4e/ts04e_03_davis_etal_1260.pdf (Accessed: 23 August 2009).

den Hertog, P. and Bilderbeek, R. (1998) "Innovation in and through knowledge intensive business services in the Netherlands, TNO-report STB/98/03, TNO/STB 1997.

Dent, R. & Montague, K. (2004) *Benchmarking knowledge management practice in construction.* London: CIRIA, (C620).

Egbu, C. O. & Botterill, K. (2002) 'Information technologies for knowledge management: their usage and effectiveness', *Journal of Information Techonology in Construction,* 7, pp. 125-137 [Online]. Available at: http://www.itcon.org/ (Accessed: 13 August 2009).

Egbu, C and Robinson, H.S. (2005) 'Construction as a Knowledge-Based Industry', In Knowledge Management in Construction (C.J. Anumba, C. Egbu, and P.M Carrillo eds.) Blackwell Publishing, Oxford, pp. 31-49,

http://www.swetswise.com (Accessed: 25 August 2009).

Fong, P. S. W. & Cao, Y. (2004) *Knowledge management in general practice surveying firms: awareness and practices.* RICS Foundation

Kamara, J. M., Augenbroe, G., Anumba, C. J. & Carrillo, P. M. (2002) 'Knowledge management in the architecture, engineering and construction industry', *Construction Innovation,* 2, pp. 53-67 *Swetswise* [Online]. Available at: http:/www.swetswise.com (Accessed: 20 July 2009).

Latham, M. (1994) *Constructing the team.* London: HMSO.

Latham, M. (1995): Getting the Act Together, Building Magazine, 1st December, London.

Mohammed, M. (2008) Knowledge Management Applications in Construction Organisations,

Unpublished MSc thesis, Department of Property and Construction, London South Bank University

Newsletters (2013a) Digital Takeoffs Deliver Surprising Soft Cost Savings, http://newsletters.viewpointcs.com, accessed 9/11/2013

Newsletters (2013b) 4Projects - Collaborating in Your Success, http://newsletters.viewpointcs.com, accessed 9/11/2013

RIBA (2013), RIBA Plan of Work, RIBA Publications, London

Robinson, H.S., Carrillo, P.M., and Anumba, C.J., Al-Ghassani, A. M. (2005) "Performance Measurement in Knowledge Management", In *Knowledge Management in Construction* (C.J. Anumba, C. Egbu, and P.M Carrillo eds.) Blackwell Publishing, Oxford, pp. 132-150

Storey, J., Bate, P., Buchanan, D., Green, R., Salaman, G. and Winchester, N. (2008), New Governance Arrangements in the NHS: Emergent Implications, NHS/SDO Working Paper nos. 3

Weston, D (2010) New Technologies in Construction and the impact and implication for Construction Project Management Unpublished MSc thesis, Department of the Built Environment, London South Bank University

Windrum, P.; Flanagan, K. and Tomlinson, M. (1997) "Recent patterns of services innovation in the UK", Report for TSER project 'SI4S', PREST: Manchester UK.