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Organisational memory and innovation across projects: integrated service provision in engineering design firms

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ORGANISATIONAL MEMORY AND INNOVATION ACROSS PROJECTS

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INTEGRATED SERVICE PROVISION IN ENGINEERING DESIGN FIRMS

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ABSTRACT

This paper provides an exploration of the dynamics of organisational remembering in firms operating through projects. The paper focuses in particular on the deliberate use of experience accumulated in the past in order to sustain innovation in the provision of services. It relies on the notions of boundary objects and brokers to empirically explore how a common memory crossing occupational and organisational boundaries is built. In so doing, it highlights how a boundary object as memory device in a project environment operates at different levels, i.e. personal, project-specific, organisational-specific and occupational specific, and how it takes different formats to perform its roles at each level. Finally, the paper highlights the role of specific communities, beyond that of specific individuals, as boundary brokers.

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1 INTRODUCTION

The literature on firm competencies and capabilities often emphasises the cumulativeness and path-dependency of innovation. Despite this emphasis, however, the capabilities approach has devoted much more attention to the processes of developing *new* skills and capabilities than to the use of existing skills and capabilities for innovation. Indeed, the evolution of sectors such as bio-pharmaceuticals and microelectronics has highlighted the importance of looking at how new competencies, based on new bodies of scientific and technical knowledge, are developed. However, even in rapidly changing environments innovation is often a matter of the re-combination of areas of existing expertise (e.g. Hargadon and Sutton, 1997). Furthermore, existing bodies of knowledge play an important role in innovation in more mature industries. An important example is the case of construction, which, over the last two decades, has experienced significant and sweeping changes in project finance and initiation. In Great Britain, probably the most controversial and extreme example of these changes has been the Private Finance Initiative (PFI), a public procurement method in which a single firm wins a contract covering the phases of the life cycle of a facility from financing to maintenance. For instance, in the case of schools, the PFI entails a single contract covering financing, design, construction and maintenance of the infrastructure as well as the mechanical and electrical services, waste disposal, catering, security, and other services for a period of 25 to 30 years. Despite a slow take-off, PFI is the cornerstone of a major campaign to renew British infrastructure, with an expected investment of about £25.5bn over three years (HM Treasury, 2002, p. 22).

There are three rationales for the basis of the PFI. The first is that the PFI would make it possible to use private capital to build public infrastructures and therefore reduce the government's borrowing requirements. The second is that by outsourcing life cycle services connected with a facility, the monitoring and enforcement of service agreements may become more efficient.[1] The third, and the one on which this paper concentrates, is that the PFI creates "a structure in which improved value-for-money is achieved through private sector innovation and management skills delivering significant performance improvements and efficiency savings" (Treasury Task Force, 1999, quoted in Robinson (2000)). In

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[1] For a concise discussion see Grout (1997). The first hypothesis was crucial when the PFI was introduced in 1992. It is however very controversial and has been essentially abandoned as a justification of PFI schemes. Readers interested in the second hypothesis can refer to Michaud (2001).

particular, by bundling together all phases of the life cycle of a facility, the PFI provides much stronger incentives than traditional procurement to integrate the knowledge related to design, construction and facilities management. The case for the efficacy of PFI therefore relies on the fact that the integration and adaptation of existing bodies of knowledge will produce significant innovation. However, while we know a lot about firm learning processes, we know little about how firms *remember* old lessons, retrieve them when needed, and integrate them into new contexts and with new competencies.

This is particularly true when activities are carried out in project form. Projects tend to differ, so that it is not easy to identify mechanisms through which competencies and experience developed in past projects can be applied to new projects. As noted by Gann & Salter (1998), while there is a large literature on project management, there is much less understanding of how projects "fit" into the firm carrying them out, and in particular how learning and the remembering of what has been learned are managed when projects are the main way of carrying out firm activities. Furthermore, recent reviews of the organisational memory literature have shown that, despite a growing body of theoretical and empirical contributions, relatively little attention has been paid to how organisations "remember" when the context of application of knowledge changes (Bannon & Kuutti, 1996; Paoli & Prencipe, 2003). However, the issue of organisational memory in project environments is increasingly important because of the growing importance of projects as ways to organise economic activity (see section 2) and because the trend toward the provision of 'integrated solutions' such as those required in the PFI is far from being unique to construction (see Davies et al., 2001).

This paper contributes to the understanding of organisational memory in project environments by empirically exploring the processes through which one large engineering design consultancy and support services provider combines and recombines memory 'repositories' in order to transfer learning across projects. In particular, the paper explores the multifaceted nature of memory repositories in project environments and the role their internal heterogeneity plays in enabling them to act as boundary objects across different communities at occupational, firm and project level. In so doing, the paper provides insights on the mechanisms through which a project-based organisational memory is adapted for sustaining innovation in the provision of services.

This paper is based on qualitative, situated research conducted as part of a three-year, in-depth case study of a large British engineering consulting firm and support service provider

(Company DE&FM, an acronym for Design Engineering and Facilities Management which is employed to maintain the anonymity of the case) which has dramatically expanded its operations in project financing and facilities management. The paper focuses on the first tool this firm developed in order to make possible Whole-Life Costing (WLC) estimates for buildings in Private Finance Initiative (PFI) projects (see below). In order to carry out this part of the research, I have examined specific bidding processes. In addition, I have examined the evolution of this and other WLC tools by gathering the company's internal documentation related to them (such as manuals, presentations and material available on the company's Intranet); by carrying out fourteen interviews over two years with the developers, users and other actors involved in the calculation of whole-life costs; and by attending three meetings between representatives of the company and the WLC system's developers as well as other actors.

The paper is organised as follows. Section 2 reviews what we know about how project-based firms preserve and re-deploy experience and knowledge. Section 3 describes the empirical context of the research. In particular, Section 3 discusses bidding as an observable organisational memory process during which the experience of different communities are integrated. This section then discusses the role of whole life costing tools as co-ordinating devices during the PFI bidding process. Finally, the case study company is introduced. Section 4 provides an in-depth discussion of the specific characteristics of the whole-life costing tool developed by the case study company. On the basis of this discussion, the section analyses the dimensions and the processes through which the whole-life costing tool acts as a boundary object across communities at project, firm and occupational level. Section 5 concludes by drawing the main implications of this analysis for our understanding of how firms manage to build on their experience despite the discontinuity of project operations.

2 WHAT DO WE KNOW ABOUT REMEMBERING IN PROJECT-BASED FIRMS?

Firms in several industries in which products and services need to be significantly customised operate on the basis of projects. Examples include construction (e.g., Gann and Salter, 2000), complex intermediate products and services (e.g., Hobday, 1998), advertising (e.g., Grabher, 2002), accountancy (e.g., Morris and Empson, 1998), film-making (e.g., DeFillippi and Arthur, 1998) and consulting in its many varieties. Firms within these industries are often collectively named Project-Based Firms (PBFs), since projects are "singled out as basic units, so that managerial responsibilities, resource allocation (men, money and equipment), and accounting data are directly or indirectly defined in terms of projects or aggregation of projects" (Warglien, 2000, p. 3).

PBFs have recently attracted increasing interest (e.g., DeFillippi, 2001; Gann & Salter 1998; Hobday, 1998; Turner & Keegan, 1999) because, although it is difficult to find data on the phenomenon, the relative importance in the economy of the activities carried out within projects seems to have significantly increased over recent decades (Söderlund, 2000). This is connected to the combined effect of much higher frequency of new product development projects in mass manufacturing industries (Wheelwright & Clark, 1992), increasing automation of both production and manufacturing activities (Foray & Steinmueller, 2001), and the growth of sectors such as consultancy (Tordoir, 1995) which are typically project-based. This growing literature, together with that on professional services firms (e.g., Maister, 1993) and adhocracy (Mintzberg, 1989), often stresses the importance of knowledge to firms operating through projects. However, the focus has tended to be on the flexible *application* of such knowledge (see, for instance, Grabher, 2002; Mintzberg, 1989; Turner and Keegan, 1999; 2001).

The dynamics of learning and innovation when operations are carried out through projects are still largely unexplored. Here, three characteristics of PBFs come together to make such exploration difficult. The first is the discontinuity of activities carried out in project form. Projects differ from one another, so that solutions developed in the context of one project can seldom be applied unchanged to another. In addition, project teams are formed and disbanded, and in many cases projects are carried out by temporary coalitions of firms that are unlikely to join forces frequently, therefore making it difficult to develop persistent organisational structures applied across projects. Furthermore, significant time spans can intervene between two similar projects, increasing the chance that what was learnt will have been forgotten by the time it is needed again. These characteristics lead to a disjunction between project-based learning and company-wide learning (Gann & Salter, 1998). What is learned in a project may be retained (if at all) by the company as the project structure is dismantled, reconfigured or re-absorbed into the company. The possibility that this disjunction will produce loss of knowledge is more or less intense depending on the uniqueness of the projects pursued by a PBF (i.e., on a combination of industry characteristics and firm strategy).

The second is that in PBFs, and particularly in professional service organisations and in the construction sector, innovation tends to be pursued within projects rather than in a dedicated R&D function (e.g., Becher, 1999; Gann, 1994; Schon, 1983). The result is that innovation tends to be incremental and organisationally distributed so that the adoption of innovation across projects needs a form of organisational memory to retrieve and adapt it to new and similar projects.

The third characteristic of PBFs that complicates the study of the dynamics of innovation is that in many industries, and in construction in particular, project managers enjoy great freedom in organising the work while their careers depend on the ability to win projects and to bring them to successful conclusions. This leads to firms often resembling confederations or 'baronies' of powerful project directors (Gann & Salter, 2003). In such a structure, changes take place as a result of negotiation processes between powerful individuals and the contingent nature of these negotiations suggests that outcomes such as innovation re-use are likely to be emergent rather than 'by design' (Mintzberg, 1989; Mintzberg & McHugh, 1985).

As a consequence of these three characteristics, innovation tends to be incremental, organisationally distributed and subject to emergent diffusion paths across projects within the organisation. On the basis of the discontinuities of operation through projects, much of the literature has put a strong emphasis on individuals as repositories of the firm's competencies.[2] This is particularly evident in the literature on professional service organisations (Morris & Empson, 1998), but also appears in Mintzberg's treatment of adhocracy. This approach implicitly or explicitly assumes that the organisational memory of firms operating through projects is 'embodied' in the organisational members and their networks of personal contacts.

However, recent research has shown that individuals, although central, are not the only repositories of PBF organisational memory. Keegan and Turner (2001) and Prencipe and Tell (2001) provide across company overviews of the initiatives undertaken by PBFs to retain and transfer learning across projects, for instance through holding 'lessons-learnt' meetings at various stages during the project and maintaining 'lessons-learnt' or project databases. Both studies report on the variety of tools, including routines and procedures, employed by PBFs to achieve this end. Davies & Brady (2000) provide evidence of the progressive routinisation of activities at bidding and operational levels for specific 'lines of

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[2] See for instance many contributions in the *Management Learning Special Issue on Project-Based Learning*, **32**(1), 2001.

business' through the development of standardised components. In a top class new product development firm, Hargadon & Sutton (1997) show the pivotal role of individuals at both operational and managerial levels as repositories of the organisation's memory. Their work identifies an "informal reference system [that] equates individual engineers with families of technological solutions" in which "upper-level managers serve as quasi librarians" (p.737). However, Hargadon and Sutton (1997) also report the widespread use of other memory technologies, and in particular routines and artefacts. In particular, they provide evidence that individuals can perform their role as memory repositories because there are "established routines for sharing the problem of current design projects with other designers in the organization who have relevant and potentially valuable knowledge" (p. 738). These routines include brainstorming sessions and Monday morning meetings bringing together all the designers. Beyond these routines, objects, in the form of toys, models and other physical artefacts, are used to provide a visually rich environment that supports the memory of designers and helps its sharing.

Beyond Hargadon and Sutton (1997), there are very few empirically based accounts of how different types of memory 'stores' interact to create an "ecology of replicators," that is a social structure in which various overlapping parts of memory are retained and can be reconstructed or re-configured as called upon to bridge project discontinuities (Cohen et al., 1996). However, these processes are fundamental in ensuring that successful innovation developed in a project is adopted in subsequent projects, i.e. that good project performance becomes a *consistent* feature of the projects carried out by a firm. The objective of the rest of this paper is to provide such an account.

3 BIDDING FOR PRIVATE FINANCE INITIATIVE PROJECTS: THE ROLE OF WHOLE LIFE COSTING

The incentives set by the PFI for the integration of design, construction and facilities management in order to reduce costs and improve quality produce effects that are particularly observable during the bidding process. Indeed, the production of a bid that is both winning (i.e., combines high quality and low price) and sustainable (i.e., is profitable over the lifetime of the contract) requires more than the simple assembly of the knowledge independently held by designers, contractors, facilities management operators and cost consultants as happened in traditional procurement. It requires the integration of their competencies into a systemic view of the facility and its operations over the lifetime of the project. In particular, this requires the co-definition of design, construction methods and level of service specification, so that the facility is designed in such a way that it may easily be built and maintained. This is a significant innovation for the construction industry. In the traditional procurement system, firms used to operate with little or no feedback between design, construction, maintenance and operations (Barlow & Newman, 1997). Indeed, as none of the traditional industry players possesses the full range of necessary competencies, firms usually form consortia to bid for PFI projects. However, many industry players, and the case study company in particular, have also expanded their in-house competencies in order to be better placed to run for these projects. In these integrated firms, bidding for PFI can be usefully seen as an observable organisational memory process in which the knowledge developed by professionals through training and on-the-job experience on previous similar projects is retrieved, integrated and adapted to the new context. Furthermore, bidding for PFI projects offers the opportunity to explore how the innovations introduced to meet the demands of this new procurement method are made a consistent feature of the PFI projects pursued by a firm, as they travel from one bid to another.

3.1 The role of WLC

In order to achieve the integration between design, construction and management required to successfully compete for PFI projects, company DE&FM was seeking to implement a variant of value engineering during bidding, which combines value engineering and target costing. This technique has been developed in manufacturing industries, but increasingly is finding application in the construction industry (see Nicolini et al., 2000). The target cost approach (Cooper & Slagmulder, 1997) reverses the traditional pricing logic, in which prices are set on a cost-plus basis. In the traditional approach, a new product is designed, costed and then put on the market at a price reflecting the cost plus a profit margin. In the target costing approach, the starting point is a market analysis of the future market requirements for the product and an estimate of the price that the market will bear for that product when it becomes available. A target cost is then calculated from the price minus an adequate profit margin. Market requirements are translated into functional attributes and the cost of producing all the attributes using current manufacturing techniques is then estimated. The cost-plus price obtained is usually higher than the market can bear. The design process then enters a value engineering process based on cross-functional and multidisciplinary workshops, which involve the supply chain, in order to find ways to produce the desired functional requirements at a price that the market will bear. Costing tools play a fundamental role in these workshops in order to guide design and production choices (Cooper & Slagmulder, 1997).

When applied in construction, costing tools with costs expressed as whole-life costs (see Figure 1) are one of the central artefacts used to integrate the contributions of designers, contractors and facilities managers during value engineering meetings (see Nicolini et al., 2000). In particular, Whole-Life Costing (WLC) constitutes the bridge that enables design choices to be linked to construction and facilities management choices, as it makes it possible to explore the consequences of design choices in terms of construction and management costs and to guide the feeding of the requirements of construction and management into design.[3] If the bid is won, the template used to calculate WLC is ideally used to manage the facility and to gather cost data in order to update cost estimates.[4] Many features of the first WLC tool developed in DE&FM are related to the relationships between the DE&FM organisational structure and the contractual structure of a PFI project. Therefore, the next section presents the case study company and its roles in PFI projects.

[3] One of the main limitations of WLC is that the reverse is not true, i.e. the state of knowledge at the moment is such that it is usually not possible (and most often it is not even attempted) to attach an (opportunity) cost in term of design quality to alternative construction and facilities management solutions (see, for instance, Cole, 2000; Vijverberg, 2000).

[4] It is important to notice that, although WLC is central in determining whether a bid could be both winning and sustainable over the life of the project, pricing strategies are also affected by strategic behaviour. In particular, in the construction industry, firms are known to underbid in the hope of recovering costs through later renegotiations. While in principle the structure of the PFI makes renegotiation difficult, firms may still underbid in the belief that the government will not leave firms running crucial infrastructures such as schools and hospitals to go bankrupt. Notwithstanding this, firms do need to know how big their bet is and to do this they need to be able to reasonably estimate costs. Furthermore, as efficiency gains are achievable through a better integration of design construction and facilities management, firms have incentives to appropriate at least part of these gains. Again, reliable cost estimates are important to select the direction of improvement.

Figure 1- WLC for Buildings

- Land acquisition costs
- Financial costs and cost related to various advisory roles before design commences
- Capital cost
    - Bidding
    - Design
    - Construction
- Occupancy costs
    - Maintenance
        - Hard FM (Fabric and Mechanical and Electrical systems)
            - Planned Preventive Maintenance (Life Cycle Replacement and regular servicing, redecoration)
            - Reactive Maintenance
        - Soft FM (Cleaning, catering, security, waste disposal etc)
    - Energy
    - FM management (including insurance)
    - Alteration and adaptation
- Disposal costs (or residual value).

3.2 The one and the many: Company DE&FM and the contractual structure of PFI projects

Company DE&FM was founded in the 1930s as a small structural and civil engineering design consultancy. During the 1980s and 1990s, DE&FM grew very quickly mainly through acquisitions and expanded its activities not only into all the engineering fields but also upstream into project financing and downstream into the new growing market of Facilities Management (FM).[5] It is now one of the largest consultanting firms in the British construction industry. Organisationally, DE&FM has split its activities into three major 'areas': Buildings, Roads and Railways, and Industry. The case study below will be concerned with developments taking place within the Buildings Area in relation to the development of WLC tools for PFI school projects. In the case of buildings, the preparation of a PFI bid involves the collaboration of three groups of professionals operating in DE&FM: designers, facilities managers and quantity surveyors.[6] In the DE&FM Buildings Area, these

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[5] The market for FM grew in the 1980s out of the widespread trend towards the outsourcing of property-related functions (such as repairs, maintenance and cleaning) (see for instance Grimshaw, 2001; Roulac, 2001).

[6] Here, designers is used to indicate both architects and engineers. In the case of simple buildings, such as schools, however, engineers are usually not required, with the possible exception of service

professions were organised into three autonomous divisions, Design, Quantity Surveying (QS) and FM. Each of these divisions had full financial reporting facilities and was valued in terms of its profitability at corporate level. Therefore, in Area B, professions remained organisationally separate, to the point that an employee remarked that the “DE&FM organisational structure preserves the prejudices of the industry” (Meeting 3).

In PFI projects, the organisational separation among the professionals working in the Buildings Area was reinforced by the contractual structure of PFI projects. These are usually run by setting up a dedicated project company, called SPV, which is the one formally bidding for the projects and which will be awarded the contract in the case where the bid is successful. The SPV then has separate contracts with the firms that provide it with the resources needed for the project. In the case of the Buildings Area, each of its divisions operated with its own contract with the SPV. The resulting contractual structure is shown in Figure 2.[7] In particular, when acting as main financer of the SPV, DE&FM Invest had the responsibility for the production of the bid, while the QS Division acted as a cost consultant to the SPV. The FM Division, instead, was in charge of carrying out the actual operations connected to the management of the building. The FM Division outsourced most of these operations, in practice maintaining very little in-house beyond the overall management of the subcontractors. Finally, the Design Division did not have a direct contractual link to the SPV but operated as subcontractor to the main contractor.

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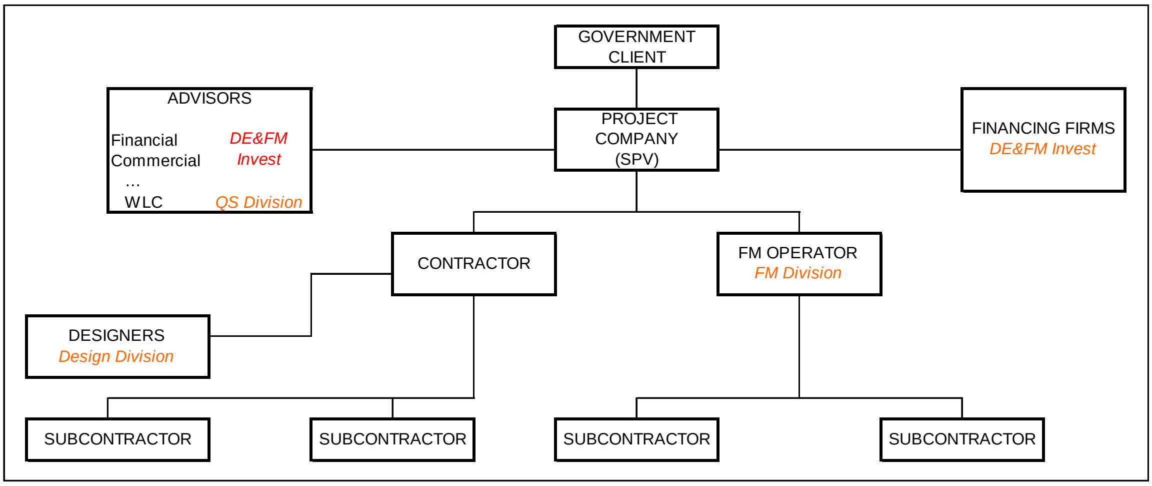
engineers. Facilities management was born as a profession in the 1970s and 1980s as a consequence of the grouping and outsourcing of property management functions related mainly to maintenance and repairs (Duffy, 2000; Grimshaw, 2001; Roulac, 2001). Despite the difficulties of facilities managers in defining the knowledge base underpinning their claim to be a new type of professional and in overcoming their traditionally low status, they have become an important new occupational group in the British built environment (see for instance Nutt, 1999; Barrett, 2000; Grimshaw and Cairns, 2000; Grimshaw, 2001). The quantity surveying profession is typically British and was born in the mid-1980s when British architects divested themselves of the measurement function (see, for instance, Male, 1990). In traditional procurement, when the architect has completed the drawings, a quantity surveyor appointed by the client measures them and produces the so called ‘bill of quantities’ listing the quantity of each materials that are needed to build the design. The bill of quantities is then used to evaluate contractors’ bids and to check the work of the appointed contractor.

[7] DE&FM Invest is a limited company created by DE&FM in order to contribute equity to the SPV.

Figure 2 – Typical PFI contractual structure and roles of DE&FM Divisions



Source: adapted from Private Finance Panel (1996) - 5 Steps to the Appointment of Advisers to PFI Projects, p. 2

As will be shown in the following section, the combination of the organisational structure of DE&FM and of the typical contractual structure of PFI projects significantly contributed to shaping the tools used to estimate the WLC of buildings.

4 AN ORGANISATIONAL MEMORY FOR INNOVATION ACROSS PROJECTS

4.1 The situated structure of the LCR model

The first attempts to deal with WLC during PFI bids involved an extension of the existing models of capital costs used by DE&FM QS Division in their traditional role of controllers of contractors and repositories of knowledge on capital cost. The resulting tool was known as the Capital Cost and Life Cycle Replacement Model (briefly, the LCR Model). The LCR Model was implemented as an Excel workbook, on a number of worksheets. It had four major components. The first estimated the Capital Cost (CC), the second the Life Cycle Replacement cost (LCR), the third other Facilities Management (FM) cost and the fourth tax and financial aspects.

In terms of Figure 1, the LCR Model split the occupancy costs into two separate blocks. The first block (LCR component) dealt with the FM costs connected to the periodic replacement and periodic planned servicing of major items, such as the replacement of boilers at the end of their service life and their annual safety checks. The second block (FM component) encompassed all the other costs related to running the facility, including the FM costs connected to the repair of faults (reactive maintenance), soft FM, energy expenditures etc.

The capital cost and the life-cycle replacement costs (CC and LCR components) were under the 'jurisdiction' of the QS Division in DE&FM. The cost classification used in both these elements followed the standard quantity surveying classification for capital costs as set by a professional association central to the industry, the quantity surveying professional association (RICS). This classification subdivided the building into 'elements' (such as roof, foundations, walls etc.). Each element was then further broken down in sub-elements, to a level of detail that made it possible to estimate construction costs. This classification had been extended to cover life cycle replacement costs, which are part of the facilities management costs as they are incurred after the facility has been delivered to the client. At the basis of this extension was the interpretation of life cycle replacement costs as deferred capital costs, i.e. as capital costs that are sustained during the life of the project rather than being incurred during the construction phase. Finally, ad hoc additions to the capital items were used to incorporate other major elements of facilities management costs, e.g. redecoration (e.g., the repainting of the walls). Sources for data with which to fill these classifications were at least partially available through public sources, maintained by the professional association of quantity surveyors.

All other facilities management costs were under the jurisdiction of the FM Division, in particular with regard to the repairing of equipment faults (so called reactive maintenance). The FM Division provided this information through a single spreadsheet (FM component), incorporating data from a pricing system internal to the FM Division and employing a completely different cost classification system based on gross floor area rather than 'building elements'. Finally, the Financial Unit in DE&FM Invest was responsible for finance and tax components, which were again heterogeneous in respect to the classification used.

This structure divided the responsibility for FM costs onto two levels. At 'role' level in the PFI contractual structure, there was the broad separation between the QS Division, responsible for advising the SPV about the entirety of whole-life costs, and the FM Division responsible for carrying out (directly or through subcontractors) the actual maintenance. At the information level, however, the QS Division employed its own cost classification and data sources for life cycle replacement and planned preventive maintenance, but relied on the FM Division for information on the other FM costs.

The structure of the LCR model, and in particular the heterogeneous cost classification systems employed, demonstrates the existence in DE&FM of distributed and partially overlapping local memories in relation to WLC. This distribution is summarised in Figure 3. Notably, in this distribution designers do not appear directly. The link of the LCR to design expertise is provided by the list of building elements, from which designers choose.

Figure 3- Subdivision of responsibilities for information related to WLC among DE&FM organisational units and the contractor

	QS Division (Consultancy)	FM Division (Operations)	DE&FM Invest	*Contractor*
Capital cost	X			*X*
Maintenance				
Planned (LCR, redecoration)	X	X		
Planned (servicing)	X	X		
Reactive		X		
Soft		X		
Financial and Tax			X	

The properties of the LCR as a tool for the co-ordination of this system of distributed cost memories are determined by the intersection of organisational structure (in particular, task partitioning across organisational units and incentive structure) and professions with their claims for specific areas of knowledge and their specific ways of managing that knowledge. In particular, the incentive properties of the organisational structures of both the DE&FM organisation and the PFI contractual arrangements described in Section 3.2 contributed to maintain the differences between the two main classification systems employed in the model, i.e. the quantity surveyors and the facilities managers. The FM Division needed to demonstrate profitability in its own right (and not as a member of a PFI team) at the corporate level. The FM Division had its own contract with the SPV, which detailed the level of performance it had to maintain over the life of the project and the price it would be paid for doing so. The difference between the cost of its operations and the price would be the profit. Therefore, the FM Division tended to provide cost information in a format as aggregate as possible in order to avoid the risk that the other DE&FM units could appropriate its margins (cfr. Nicolini et al. (2000) for a similar situation across the supply chain). The result is that cost information in the FM component of the LCR model was far less detailed than the components managed by the QS Division and not immediately linked to design variables as in the other components.

Furthermore, because of the way in which the construction industry has been organised, information on FM costs was not collected systematically like information on capital costs, which have been at the core of an independent profession for over a century. The FM Division did have cost data, but, unlike the quantity surveyors who tended to collect cost information in databases, it was organisationally dispersed. The FM Division assistant commercial manger gathered cost information on an ad hoc basis by asking for quotations to subcontractors or to FM Division units responsible for the purchasing or carrying out of specific services (e.g., the purchase of energy or waste disposal) (Interview 54). Furthermore, the FM Division had potentially available a great quantity of data on fault patterns and life expectancies of building components through the software systems that had been used to manage the service. However, the FM Division was only then beginning to consider the idea of making use of these data (Interview 57, Head of the FM Division Information Systems). Therefore, the different way in which the quantity surveying and facilities management professions managed their memory as professions also contributed to make the classifications employed in the LCR heterogeneous.

4.2 Life Cycle Replacement model as a boundary object for shared memory in a project environment

The previous section has demonstrated that DE&FM organisational memory is in fact made up of several local memories, and that these memories and the way in which they are brought together are shaped by both the professional affiliation of those who build and use them and by their engagement in the practice of their profession in the context of a specific organisation. In other words, these memories are developed within specific intra-firm communities of practice, whose members are also members of networks of practice through their professional affiliation (see Brown & Duguid, 2001).

When the PFI brought about the need to integrate these local memories, the LCR model emerged as a boundary object partly crossing professional and organisational boundaries and partly reproducing those boundaries in its own structure. Notably, the LCR model as a boundary object emerged as an evolution of a costing tool for capital costs, which was firmly in the domain of the quantity surveying profession. The need for integration projected the tool outside the QS community, partly extending the role of quantity surveyors to estimate some of the FM costs, but also incorporating the cost structures of other communities, in particular the facilities managers and the tax and financial experts. In this respect, the structure of the LCR presents some of the features of classification systems acting as boundary object discussed by Bowker and Star (1999). In particular, the LCR classification shows a growth process in which competing views are stitched together, rather than one in which consensus evolves across the different occupations. For example, FM costs are stitched onto the usual elemental cost build up for capital costs, and 'tax allowance forms' are stitched in to allow financial experts to make their input. These three sets of cost information do not 'talk to each other' as the classifications do not match and it is not known how to reconcile them, apart from summing costs per square metre or per pupil.

Furthermore, the organisational structure of DE&FM coupled with the contractual structure of a PFI project lead to an 'erasure' strategy on the part of the FM Division.[8] This, combined with a much more distributed and less detailed collection of cost information in the FM Division than in the QS Division, makes FM cost classification different from QS Division classification. In Bowker and Star's (1999) terms, this is a boundary object born out of the collision of at least three different naturalised classification systems (quantity surveying, facilities management and financial).[9]

As a memory tool, the LCR model works on a number of levels. In particular it links:

- short-term, project specific memory and long-term, across-projects memory
- occupational, organisational and individual memory
- static and dynamic uses of memory.

4.2.1 Short-term project specific memory and long-term across-projects memory

At the start of a project, the LCR model is a hollow shell listing categories of costs. These categories represent one aspect of the long-term memory of costs connected to buildings. The long-term, cross-projects sources and repositories for cost data sit largely outside the model itself and remain within the sphere of the specific occupations. In the case of the quantity surveying profession, these are the cost databases maintained by their

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[8] Bowker and Star (1999) define 'erasure' as the purposeful deletion of part of the information consigned to a form of social memory on the part of a group with the purpose of preserving independence.

[9] D'Adderio (2003) provides an example of a case in which the need for integration does not produce the emergence of boundary objects but simply the extension of the structure of memory of one function to the others.

professional associations. In the case of the facilities management profession, data reside in the expertise of people involved in the purchase of specific services.

The process of filling the shell with project-specific data creates 'instances' of the tool which act as devices that contribute to the co-ordination of decisions across occupations, in particular with regard to design, construction and facilities management. In order to allow such co-ordination, the LCR serves both as a negotiation device and, from a control system perspective, as a short-term memory to maintain a record of status. Because publicly available data are considered less reliable and unable to provide a sufficient competitive edge, cost consultants build collections of instances used for cost estimation in later projects, (Interviews 45 and 46, DE&FM Bid Managers, but see also Ashworth, 1996; and Cole, 2000). Thus, in addition to the role of its underlying classification system for maintaining long-term memory, the LCR model sustains long-term memory through the use consultants make of these collections of instances. This also has a very practical aspect, as cost consultants select a project that they consider similar to the current project and use the instance related to that project as a starting point for the development of the new instance. This is common in both the legal and accountancy professions, where consultants tend to build stocks of partially reusable material (Steinmueller, 2000). This behaviour contributes to the persistence of patterns of action and, therefore, to the stabilising role of management accountancy systems (see Hedberg and Jönsson, 1978; and Cooper et al., 1981).

The LCR is thus a tool for both short-term memory of status on a single project and longer-term memory across projects. The memory is maintained through the collection and retention of instances, the use of a locally adapted classification system and publicly available data that is accessed using roughly stable industrial classification systems.

4.2.2 Linking occupational, organisational and individual memory

Much of the long-term memory aspect of the LCR model is linked to occupational specialisation, in that its structure, at least for capital costs, is based on a standard industry classification employed by quantity surveyors throughout the UK. This system is partially customised to fit the local context.[10] Furthermore, publicly available sources of cost-relevant

[10] Here the context means the type of building, the particular organisational set up of the company and the contractual structure for PFI projects. Adaptation of the BCIS classification to the context can be seen both in the slight variations across categories for different types of buildings in the cost surveys published by trade magazines such as *Building*, where a few categories are missing.

information maintained by occupation-specific bodies such as BCIS are often used to fill in the structure with data. The structure of the LCR model in terms of its organisation in four components bridges the occupational and organisational contexts by accommodating intersecting patterns of division of labour across occupations and across units within the firms.

The LCR model also acts as the external memory for the individual cost consultant and helps him to perform hise role as memory co-ordinator. Individual consultants 'own' their collection of instances, which are a private resource for the construction of professional competence and reputation (interview A, WLC cost consultant, QS Division).

The LCR therefore lies at the intersection of the personal, occupational and organisational memory domains.

4.2.3 Linking static and dynamic uses of memory

When compared with the spreadsheets that were traditionally used for the calculation of capital costs, the LCR shows the first signs of a transformation from a static representation of a single building into a dynamic representation of a number of potential buildings through the specification of alternatives for some elements. This is the first step required in using the tool for optimisation rather than pricing purposes. As a pricing tool, the LCR would be (like the traditional capital costing tools) an object for the 'internal' use of the quantity surveying profession. As a dynamic tool used to optimise design and level of facilities management services specifications, the LCR needs to become an object which is able to co-ordinate various communities. The structuring of PBFs as 'confederation of baronies' and the properties of the incentive structure have produced an object that has emerged as a mediator across the views of the different communities, i.e. a boundary object where different and competing views are represented.

4.3 Innovating across projects

The LCR model may also be analysed for insights into the processes of development and adaptation of organisational memory supporting innovation in PBFs. Of particular interest are innovations that require the integration of knowledge 'hosted' in separate parts of the company. In turbulent environments, one of the major characteristics of organisations working through projects is decentralisation, as procedures and tools need to be adapted to the local context (Galbraith, 1969; Knight, 1976; Mintzberg, 1989). The main consequence of such decentralisation is the prevalence of adaptive and grass-roots learning processes over top-down, imposed changes (Aoki, 1986; Mintzberg and McHugh, 1985; Mintzberg, 1989).

The LCR model shows how adaptive, incremental processes that take place within projects are used to adapt a set of distributed local memories to the needs of a new procurement method. The LCR model had been the result of work carried out by quantity surveyors working on PFI projects, with no R&D funds for it. The usual classification of capital costs was used to tackle the problem of life cycle replacement costs once these were interpreted as 'deferred capital costs'. Similarly, significant planned preventive maintenance was tackled in an incremental way, through 'appendixes' that incorporate actions connected to elements, such as redecoration of internal walls. What is consigned to the memory of the organisation also "emerges in an unintended shape as a result of practices directed to immediate ends" (Douglas, 1987, p. 69).

5 CONCLUSIONS

This paper has used the concepts of community of practice (Brown & Duguid, 1991; Lave & Wenger, 1991; Wenger, 1998), networks of practice (Brown & Duguid, 2001) and boundary objects (Star & Griesemer, 1989) to shed some light on the processes through which organisational memory in PBFs bridges project discontinuities and supports the diffusion of innovation across projects. In so doing, this paper has provided an empirically based account of how different types of memory 'stores' (e.g., classification systems, accountancy tools, cost consultants) interact to create the "ecology of replicators" (Cohen et al., 1996), enabling both continuity and adaptation across projects. These theoretical concepts provide a very concrete means of analysing the organisational groups in DE&FM and the specific role of the LCR model as a boundary object in bringing together these groups.

The case study shows the emergent, incremental and negotiated nature of the memory processes of PBFs. The analysis of the LCR model and its use shows how the management of cost memory relies on a number of heterogeneous repositories, ranging from industry data sources to the experience of an individual consultant. As a boundary object, the LCR tool allows these heterogeneous sources to work together by structuring the process of remembering through division of labour and division of knowledge. In this distributed context, cost consultants in the QS Division act as memory co-ordinators of all these distributed pieces of memory and pull together the memory of the systems during value engineering workshops (see also Ackerman and Halverson, 1998).

In order to perform its role, the LCR is in itself heterogeneous. The LCR model is something between a project-specific boundary object, a boundary object across professions over a number of projects, and a boundary object enabling the individual to both build upon and contribute to occupational and organisational construction of memory. As such, it has emergent properties that depend on both the initial distribution of expertise and memory and on the incentive setting in which it is developed and used. It is composed of a 'structure' provided by the three cost classification systems (quantity surveyors, facilities management and financial) and the way in which the LCR tool is articulated, i.e. the way in which the LCR uses the classification to calculate costs (for instance, the stitching together of different classifications in the form of the sum of partial totals). It has space to incorporate publicly available industry sources on costs. It also consists of a collection of 'instances' of the model from previous projects, which builds up a long-term memory.

Finally, the tool is static in the sense that it provides the cost of a given configuration, but it does show some tendency to become dynamic in allowing for comparisons of selected alternative configurations. It is a pricing tool that, with some modifications, can become an optimisation tool. In order to accomplish this DE&FM will have to attend to the problems of further stabilising and standardising the underlying data used by the LCR tool. Doing this is no small task since it exposes the specific gains sought by distinct groups within the company and threatens to displace the expertise of those who currently maintain the data components of the LCR tool (Cacciatori, 2004).

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