Knowledge across cultures in the construction industry: sustainability, innovation and design

Adrian Demaid*, Paul Quintas

Department of Design and Innovation, Faculty of Technology, The Open University, Walton Hall, Milton Keynes MK7 6AA, UK

Abstract

In the construction industry both the design and management processes differ significantly from the stylised models usually promoted in the academic and business press. To the complexity that is normal business in construction industry projects add the uncertainty associated with the changing legal and ethical imperatives of sustainable development and the result is a mess. Innovative products, together with the companies that make them, are being built on the back of a rigged market in recycled raw materials and policy changes are spawning unintended consequences.

Making sense of those processes that use knowledge about sustainability, at the level of the firm, is particularly daunting because companies behave differently in different international contexts. The problem is further complicated by the collaborative nature of projects; specialization and the need to communicate with and between experts increases both costs and uncertainties.

We discuss a fundamental tension between understanding knowledge creation and use, and the drive to capture processes in formal documents and systems.

We propose similarities between developments in the field of sustainability and developments in the field of risk, with risk having the advantage of being further down the evolutionary line. Both fields have strong dimensions of formal rules and socio-economic behaviours. Such complexity, we argue, requires a number of perspectives to make sense of how knowledge is used in construction and allied industries.

Keywords: Knowledge management; Construction industry; Sustainability; Risk

1. Design and sustainability at the level of the firm

The formal processes of design and bidding in different industries are usually portrayed as some sort of flow diagram such as the one shown in Fig. 1, which is from a major European construction company. This fragment of the complete diagram shows the start of the bidding and design process for a private finance initiative contract by the company. The process, which is managed by a series of approval stages, continues in a similar way until it converges on an agreed solution, including a Whole Life Cost (WLC) analysis. Risk and value management procedures are built into the process at critical points on the path to punctuate the process.

In current construction industry practice the equivalent sustainability procedures tend to be additions to the core processes, which are invoked according to specific requirements of context and practice; public projects such as schools and hospitals lead the way in the UK. Internationally those global companies that feel vulnerable to political pressure and mass action, such as BP, are also in the vanguard.

Integrated capital works project companies provide the framework and the knowledge processes that make large contracts in the urban environment work. They assess and develop designs according to agreed objectives; they incorporate easily available knowledge and take specialist advice in difficult areas in order to minimize risk and provide value for money in order to win a contract.

It is not in such companies’ interests to instigate innovative solutions, whatever the notional imperative, as this would add to the risk, together with its concomitant up-front costs. So, environmental solutions that are not cost-effective will not be proposed unless instigated by clients, demanded by legislation or come from accepted, local business ethics.

At all of the stages in Fig. 1 knowledge and its constituents of data, rules and procedures is being created
and destroyed, transmitted and used in a complex, rich picture of human activity. In practice, these schemas are used subtly according to particular contexts. This is the knowledge dimension—these systems are made to work by human beings.

2. Formal systems in practice

For a research review on how human beings put such design representations into practice, by reflective processes, see Reymen (Reymen, 2003). However, here is an insider’s interpretation of different approaches to design and bidding for major contracts in the field:

Do what we have always done—take the easy way out.
Do what we did on the last project—flavour of the month.
Do what the Project Director wants—always very tempting, but not always the best solution.
Follow the Design Team’s design—can be good, but likely to be unaffordable.
Do what the Client wants, but can not afford—wonderful design, but would not get the job.

Many interested parties, from inside and outside of the firm, influence design decisions. A company’s design managers have to act across different functions to address conflicting objectives from, for example: buyers, planners, bid managers, outside designers and subcontractors, project managers, architects, clients and legislators.

Critical design decisions are made throughout the process; not simply during design development but also at purpose specific reviews concerned with, say, safety or cost during program development. Progress checking is not simply paperwork or algorithmic exercise; it takes place in meetings, workshops, corridors and ‘down the pub’.

There are lessons to be learned from the world of risk that are relevant to understanding sustainability. Formal processes for assessing risk and value are relatively mature but risk assessment also has a strong cultural element. David Hancock (Hancock, 2004) uses, as an example, how lessons learned from an accident on the London Heathrow Airport’s Express construction project fed into the Heathrow Terminal 5 project to argue that there is a balance between formal procedures and social attitude to minimize risk in major projects. He maintains that much of the cohesiveness amongst partners on the Terminal 5 project resulted from systems lessons learned in the aftermath of the Heathrow Express accident:

“From a planning perspective the project came up with the concept of ‘Last responsible moment’ and from the risk perspective we introduced the concept of risk champions and facilitated risk workshops. With these methods the stakeholders were allowed to seek different solutions as they explored divergent and convergent aspects of their views. At this point, they would be engaging in dialogue. Rather than arguing their respective positions and trying to persuade the other their solution was the correct one, they would start rethinking together, some of their basic assumptions. This proved to be problematic at first as the members felt vulnerable and trust was lacking between the various contractors but as time progressed and they realized they were both seeking satisfactory rather than optimal solutions they continued to talk together to explore solutions. Those solutions ranged across economic, political, social, and cultural considerations. They talked about the short-term fixes and long-term solutions. At some point during this process they would realize that they shared common ground. This essentially meant both realized that their differences were less significant and profound than what they shared in common, and that this common sense began to form the basis of the integrated T5 solution.”

If formal procedures for risk and value management can be built into the management processes for major projects then sustainability issues can also be integrated into core procedures, rather than treated as additional, secondary constraints.

3. Industrial chameleons

Companies that respond to different customers’ business ethics, different legislative frameworks and different national business practices need to adapt their procedures for specific bids and design briefs.

This issue is not confined to new developments in cultural values, such as the rising prominence of sustainability, but is at its sharpest focus where there are significant financial consequences for mature practices that take place in different business environments. Maurya McClintock (McClintock and Andersson, 2000) compares the design process in the US and Europe, emphasizing early design collaboration in Europe:

“The most striking feature of the European design process is the degree of collaboration very early in the design process. The architects, engineering disciplines, cost estimators, contractors, manufacturers, and specialist designers/contractors (such as facade engineers or contractors) are often brought together as early as concept or scheme design.”
So, the schema shown in Fig. 1 would be understood, in principle, by a US designer, but interpreted differently because of socio-economic imperatives. A US designer works in an intensely litigious society where something new and unproven is viewed as carrying a high level of risk and therefore potential for costly court action whereas our European company maintains strongly that it is not in the risk transfer business. McClintock also comments:

“The design-build process is currently very popular in the US because of the misconception that the contractor assumes all of the responsibility and thus all of the risk and potential litigation. This view, however, is not totally accurate. By using design-build, the client has really only bought insurance.”

Business ethics are also notably different in the international arena, particularly when concerned with issues about sustainability.

3.1. Case study 1

A company that makes floor coverings for the global office market is based in the USA, with offices and a large market in South East Asia. The carpets that they supply and fit as part of the original contract are lifted at the end of use and shipped back to the USA for recycling in a purpose built plant. The old carpet is recycled to produce backing for new carpets produced in plant adjacent to the recycling plant. This taking away of the old carpets and shipping them half way across the world for recycling is not dependent on a new order for fitting out the office block or airport.

However, the company is building a new plant in China where this recycling contract that is so much part of the company’s self-narrative and stated values will not apply. The yarn will come from the USA but the backing will be sourced locally. It is argued by the company that the cost of purpose built recycling plant is prohibitive, but as well as a favourable economic and supply chain environment in China the company is free from home pressures for recycling credentials.

3.2. Case study 2

An international office fit-out company in South East Asia always produces an environmental audit for its bids, but this is not taken seriously during the commission of successful bids unless specifically demanded by the customer. BP, for example, is acknowledged as having high standards and requiring extensive documentation about sustainability issues that stretch the knowledge of the fit-out company. Key staff at the company’s Asian office are unaware of how far developed the sustainability procedures, and associated formal documentation, is in their London office.

A senior manager who we asked about sustainability in the office fit-out market commented:

“Our eco-products are a way of grouping together dissimilar products, rather than them being a jumble of unrelated items, and sustainability is a great way of influencing trendy young designers.”

Formally represented systems clearly require a great deal of situated knowledge to make them work in specific national contexts and a world of changing business ethics.

4. Knowledge processes

Knowledge based systems are a subject of continuing interest in a number of academic disciplines and different application areas—from engineering to medicine. In the early days of the Artificial Intelligence movement they promised computing solutions to the problem of capturing knowledge in industrial and business environments.

Expert Systems that used forward and backward chaining to search rule bases for solutions to queries and hierarchical structures of objects that inherit characteristics according to strict inheritance rules were both created to model the structures of technical knowledge. Computer scientists working in the field aimed to produce solutions to complex problems that would otherwise have required expensive technical specialists. Multiple inheritance and delegation mechanisms in object-oriented computer languages, where an object inherits characteristics from more than one generic hierarchy, offered some hope for providing computable solutions for complex problems (Demaid, 2002).

However, seemingly straightforward systems proved to be remarkable resistant in capturing such formal representations, as for example the legal domain. At first sight the modelling of legal precedent seemed to be an application area well suited to logical representation and automatic execution, but extensive efforts to model aspects of the law failed for fundamental reasons (Leith, 1986). Hopes for computable intelligence and the, less challenging, ambition of automating specialist knowledge have faded, but the driving forces for knowledge representation remain strong.

The current metaphor for knowledge representation is the many-linked world of the Web, hence the term ‘semantic networks’. Networks, graphs and mappings applied to practical problems in innovation, technical representation and procedural management abound: Fig. 2 (Folkes and Quintas et al., 2004) portrays some of the variety of uses to which different types of mappings have been applied.

The processes associated with many network representations is navigation aided by computation: more obviously a ‘working’ map to aid a practitioner, or represent a problem domain, than an expert system dedicated to producing computable solutions.
The everyday mix of business processes and technical solutions give rise to ill-structured problems that are amenable to a number of successful solutions using a number of potentially successful strategies. Herbert Simon’s writings through the 1960s (Simon, 1962; Simon, 1973) describe these types of problems superbly, although his great hope that they might be susceptible to solution using very large rule-bases—the foundation of the artificial intelligence and expert systems movements—failed.

The beneficiaries of Simon’s legacy use rich pictures to portray what Horst Rittel calls wicked problems (Rittel and Webber, 1973) and Robert Horn calls social messes (Horn, 2003). In this catchy-named body of literature the notion of a computed solution is abandoned—no inference engines—and the imperative is to portray knowledge so that the issues which might lead to the realization of alternative approaches or to the understanding of conflicting positions are exposed.

Used without rigour rich picture representations can simply demonstrate just how complex, or messy, a problem is; with rigour they can portray argument and represent process. For example, applied psychologists use rich pictures as a precursor to the application of professional knowledge and soft systems theory in order to create structure.

The pictorial representation of narrative, dialogue and argument can be the means by which a process is abstracted; Horn describes his work as ‘using a visual language to model and communicate complex issues’; Fig. 3 shows his powerful portrayal of the development of two religious positions.

Inevitably such ideas are encapsulated in computer-based tools that are designed to constrain their use into some sort of formalism—to provide rigour. Rittel’s issue-based information system, designed to support discussion, led to dialogue mapping and the portrayal of argument using the software Compendium. Such tools are used to provide support for knowledge representation and corporate decision making (Selvin and Shum, 2002).

Portraying knowledge used in the industrial context of a collaborative project by means of maps and computer based tools to portray narrative and argument requires the detailed consideration of knowledge specialization and communication between specialisms.

The division of knowledge is a fundamental characteristic of modern industry and business that has its antecedents in Adam Smith’s division of labour:

“Adam Smith explained the wealth of a nation by the division of labour which led to the growth of differentiated knowledge (Loasby, 1999).”

Specialization amongst collaborators causes concomitant problems of knowledge sharing in and between companies and project teams. Knowledge created in specific contexts such as a project is, to a large extent, ‘situated’ (Lave and Wenger, 1991) and much experiential knowledge created in practice remains tacit and so is difficult to transfer (Quintas, 2002). There is therefore a fundamental tension between the degree of distinctive knowledge specialization implicitly represented by nodes on a flow diagram, such as that shown in Fig. 1, and the ability to communicate and share knowledge to the extent that is needed in order to make such a system work.

This issue clearly raises important questions about implementing change in project processes and technical...
innovations in the construction industry; changes such as the movement towards Design & Build contracts, the integration of sustainability imperatives into project planning and the use of innovative products using recycled materials.

The communication processes embedded in a normal business environment, at the level of the project, take into account the degree of overlap in knowledge at different stages of the process. Mature processes ‘shake down’ so that people know their own roles and how much they need, or do not need, to know about other people’s roles. Gaining new expertise in a project is very costly for the individual and does not necessarily have an immediate benefit for the company.

However, some knowledge about other’s specialization is necessary for communication about that expertise and in order to have confidence in the process of gaining and incorporating the results of their expertise. It is also vital to know when to relax control of the agenda in a new situation. Our own work (Demaid and Quintas 1999) has shown that too much compartmentalization of expertise can exclude critical knowledge from a project at great cost.

In mature, rehearsed project processes locally generated knowledge becomes embedded, or internalized; (Weiss and Bucuvalas, 1980) observe:

“Information geared to ‘decision points’, ‘decision deadlines’ and ‘decision makers’ may be relevant in a surprisingly limited number of instances. When most people most of the time operate from a knowledge base that they have acquired informally and haphazardly over time, research and analysis have to become incorporated into that base if they are to become influential.”

Knowledge about sustainability is yet to become embedded in project procedures and there is no consensus about the important issues. Furthermore the results of externalities, such as legislation that seeks to improve the urban environment are not always, or even usually, rational or predictable.

5. Green intentions—black results

The notion of a commonly termed ‘law of unintended consequences’ comes from the sociologist Robert Merton’s influential article on the unanticipated consequences of socially motivated actions (Merton, 1976). For example: Bodurtha (Bodurtha, 1976) explains that introducing pollution control equipment led to an increase in the frequency of fires and explosions. Reducing the air in a furnace to prevent the formation of harmful nitrogen oxides produces a fuel-rich mixture that can, and has, become explosive, and collecting dusts dry to reduce dust pollution and water contamination has led to dust explosions.

Merton classified his field into five types. The first two, Ignorance and Error, although common, are of little interest but the next two types, which he titled Imperious Immediacy of Interest and Basic Values, abound in the field of sustainability. Immediacy of Interest means that the desire for the immediate consequences is so strong that the unanticipated consequences are ignored; this is wilful ignorance. Basic Values, Merton argued, was where the unanticipated consequence is the destruction of the desired effect—how the protestant work ethic by creating wealth destroys protestant ethics is his example.

Our own work on glass recycling (Demaid and Quintas, 2004) argues that the widespread belief that the collection of glass bottles is inevitably good for the planet is a myth that the glass industry works very hard to bolster because it has a vested interest in sustaining public commitment to glass
bottle collection; otherwise the industry might be required to bear the on-cost of disposal.

Glass recycling is promoted by government targets, and reinforced by public subsidy, private effort, taxation penalties, and regulation. However, when the energy costs of recycling are taken into account many of the perceived environmental benefits are negated. The reduction of energy used in primary glass bottle production by adding recycled cullet, the sorted and cleaned chips of used glass bottles, is small and the distance travelled by old bottles is very great: Ireland exports all its collected glass bottles and England exports a third of its green glass bottles. So, there is a significant energy cost to the planet, in addition to a financial cost to the misled consumer.

The environmental cost of all household packaging is only 7% of the total household impact and yet, in 1999, 46% of households thought that their best action for the good of the planet was to recycle bottles and cans (Bickerstaffe, 2001). The power of this grand narrative on glass recycling, which is reinforced by every passing council waste collection vehicle and every visit to a supermarket car park, is such that when attempts to change the system are tried the result is, inevitably, an outcry:

“N.Y. Will No Longer Recycle Plastic, Glass’ Recycling in New York City will be reduced to paper and metal, eliminating the recycling of plastic and glass. ‘No other big cities have taken a step back like this, and I am not even familiar with any smaller cities taking out elements of their recycling programs, ’ said Laura Haight, of the New York Public Interest Research Group. New York Mayor Bloomberg says the move was made to save the city money. [LA Times, 7/1/02]”

More than a third of waste paper and plastic collected in the UK is being exported 8,000 miles to China (Vidal, 2004):

“China is buying up everything it can. It is sucking in material from all over the world and it does not give two noodles what it takes, said one plastics recycler who asked not to be identified. “I know of 300 firms, mostly in China, offering to buy my plastics. I have three or four companies cold-calling me every day from China requesting material. They have very cheap labour to sort the material but the shame is that it is being done there and not here. They do not care about the quality, or the contamination. No one checks what is sent or what arrives.”... “The Chinese put me out of business,” said Edward Clack, a plastics recycler who invested in two recycling plants in Britain. “Everyone has lost supplies to China. The local market is being starved of materials. Hundreds of brokers are buying up the plastic and shipping it out. It is cheaper to send a container to China than to Scotland”.”

This evidence makes for an interesting conjunction with our case study on recycling plants that turn old carpets into the backing material for new carpets.

From the point of view of managing innovation the effect of these rigged markets in raw materials is fundamental. For example, collected glass cullet is the raw material for new products such as bedding material for pipe laying (in competition to gravel), drainage material (when this is used in landfill it can both command a premium and escape landfill tax), glass ‘terrazzo’ and decorative concrete in the construction industry.

Industry has to accommodate to intended, unintended, rational and irrational effects when addressing sustainability issues; the knowledge base is unstable.

6. Discussion

How knowledge is used poses difficult enough problems for the usual business processes of design and bidding for large construction projects. It is a crucial balance between formal, contractual and legislated processes and the business cultures in which they take place. When sustainability issues are added to the mix this creates more uncertainty for managers and more opportunities for the creation of innovative products using recycled materials. Working in local contexts that result from different national and international priorities for sustainability and different national business ethics produce an industrial world that is complex and liable to rapid and unpredictable change.

Adding measures of sustainability to existing project procedures, such as the UK’s Building Research Establish- ment Environmental assessment Methodology (BREEM) rating, supports an agenda for change but a conservative business ethos in the construction industry ensures a pragmatic response to rating measures:

“We implement all of the measures that are cost-free, check our rating then move up the cost spectrum until we reach our target.”

Lessons from the perspective of risk in projects teach us that formal procedures are not enough to fundamentally change industrial practice and that adding measures to existing formal procedures does not work well.

Any single perspective is insufficient for modelling design, bidding and execution processes in collaborative industries operating complex systems—Picasso-like we want multiple perspectives in a single image.

In our collaborating firm sustainability issues are much less developed than those associated with risk, a field that also combines cultural and formal perspectives. Risk and value management are cornerstones of design and bidding procedures in the construction industry—for sustainability to gain importance requires new understandings and more careful legislation.

A fiercely contractual approach to collaborative work has effects other than the perceived benefit of insuring against risk and maintaining control: a collaborator’s deep expertise
can be managed out of a project to the detriment of the joint activity. However, taking on board deep expertise can be a costly managerial process in a strong hierarchy because of specialism’s barriers to knowledge acquisition.

To add a knowledge perspective to collaborative project processes requires us to consider the relevance of the domain of knowledge management. We have emphasized the situated, or context specific, dimension of knowledge, espoused by Lave and Wenger (Lave and Wenger, 1991) for knowledge created during the course of a collaborative project and Weiss’ (Weiss and Bucuvalas, 1980) commentary on the limitations of internalised, or locally embedded, knowledge. We also emphasise the importance of tacit know-how that can be learned only by experience, as described by Michael Polanyi (Polanyi, 1967). David Landes (Landes, 1998) uses this example to support Polanyi’s view of knowledge:

“In 1916, in the hot middle of World War I, the French had lost some of their major centers of arms manufacture and desperately needed an additional supply of their 75-mm field guns. This was their key artillery piece, the pride of their arsenal, a machine so exquisitely designed that a glass of water perched on the carriage would not spill when the gun was fired. Violating all of their rules of secrecy, they sent the blueprints to the United States—to no avail. Not until a team of workmen went over to show the Americans how, could they get pieces of comparable firepower and stability.”

Despite such powerful body of work, dating back many years, there was an eager audience for Nonaka’s spiral model of knowledge conversion (Nonaka, 1994; Nonaka, 2000), which offered a route from tacit to explicit knowledge—from the individual to the firm. Tacit-to-explicit is a process that appeals to organizations seeking to ‘capture’ valuable knowledge, even though the very foundation of the notion of such ‘conversion’ is questionable (Brown, 1999).

Computer based tools cluster down at the formal end of systems analysis—computers are about information and data processing after all—and so the Expert Systems community was ready and waiting for this new outlet for their skills. This holy grail of converting tacit to explicit knowledge, which fails to understand the nature of tacit knowledge (Tsoukas, 2003), is likely to suffer a similar fate to that of automating legal advice.

There seems to be an inexhaustible and recurring demand for easy solutions to ill-structured problems, but there is a gulf between the formal, information-processing end, of the knowledge spectrum and the way that complex systems can be portrayed using narrative and information representation without the promise of an algorithmic solution. Nevertheless the rich field of innovative products and difficult management issues created by the sustainability imperative is beset by standards, measures and procedures predicated on the notion that ill-structured problems can be ‘solved’.

Managing knowledge for sustainability presents an array of complex problems that demand serious, interdisciplinary responses. The examples explored in this paper suggest that there is not only huge scope for misunderstanding, but that there is a high risk of misinformation, misinterpretation and misplaced ‘faith’ substituting for knowledge and understanding.

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References