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Hidden innovation in the construction and property sectors

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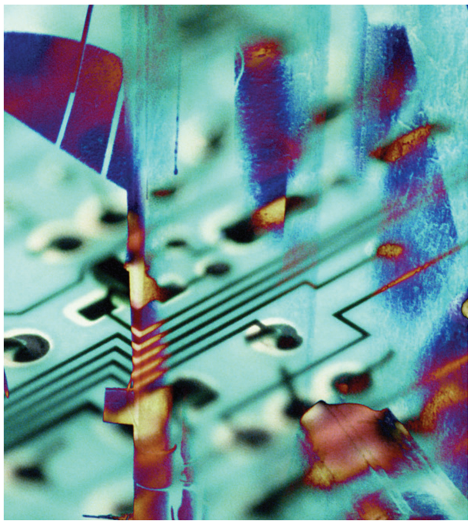

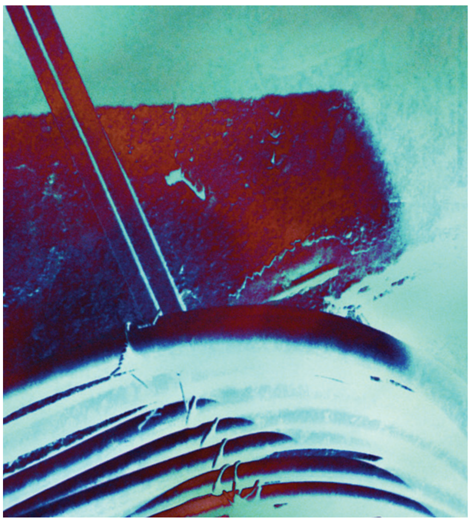

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Hidden Innovation in the Construction & Property Sectors

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Abstract

The construction and property industries have a poor reputation for innovation. Indeed, this reputation appears to be backed by official statistics which projects these industries as being devoid of innovative activity. However, the reputation is undeserved. Official statistics misrepresent the extent and nature of innovation in these sectors. A closer analysis reveals that much of the innovation that exists in the sector is hidden from conventional measures. By its nature therefore, it is difficult to measure the precise extent of this innovation and disaggregate it from general improvement. This opaqueness strengthens the need for policymakers, practitioners and researchers within, amongst others, the surveying sector to go beyond the visible spectrum of innovation and design and implement appropriate policies, knowledge bases and practices which engage and leverage the hitherto hidden aspects of innovation.

1. Introduction – the scale and importance of the sector

Construction activity has changed in response to new demands over recent decades, but a new wider perspective is needed to continue the optimal alignment of construction activity with the changing needs of the economy and society. The role of built assets in the development of a nation needs to be considered. To do this broader measures of the economic value of the built environment are needed in order to allow an evaluation of its contribution to prosperity and quality of life. From this the value of the role of construction can then be properly understood.

The definition of construction used in the interpretation of construction activity in the International Standard Industrial Classification (ISIC) is very limited, namely:

Economic activity directed to the creation, renovation, repair or extension of fixed assets in the form of buildings, land improvements of an engineering nature and other such engineering constructions as roads, bridges, dams and so forth.
(United Nations, International Recommendations for Construction Statistics)

This standard definition does not include other value-adding construction activities such as:

- *Upstream* - manufacturing, mining and quarrying, architectural and technical consultancy, business services.
- *Parallel* - architectural and technical consultancy.
- *Downstream* - real estate activities.

The construction sector consists of much more than merely on-site production. The entire built environment, as distinct from the natural environment, falls into the field of activity of construction. A framework for a mesoeconomic analysis of the construction industry including service, management and stock aspects has been developed by an international group of economists[1] and this construction sector system is depicted in Figure 1. Here the role of the quantity surveyor would largely fall within the new construction area, whereas building surveyors and general practice would largely operate within the following management of the service sector.

This highlights the entire life-cycle that begins with the extraction of the raw materials at the mining stage and ends with professional services such as management, architecture, design and facilities management. Although some of these areas do not lie within the SIC code of construction (45), it can easily be seen that they are directly attributable to construction. This broader view has a dramatic effect on the contributions the construction industry gives to the UK economy.

There is a significant difference between the narrow and broad definitions and the resulting impact the construction industry has on the economy. Based on UK Input-

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[1] The construction sector framework approach was developed by a project group from the W55 [Building Economics] and TG56 [Macroeconomics for Construction] of the CIB (International Council for Research and Innovation in Building and Construction). The economic sector system as applied to the construction sector is close to the concept of "construction product system" suggested by Australian industrial economists (AEGIS, 1999).

Output tables for 2005, SIC code 45 *Construction Work* gives a Gross Value Added (GVA) as a percentage of total GVA of 6.2%. The addition of other SIC codes, or part SIC codes, falling within the boundaries of the broader definition gives a more appropriate valuation for the contribution which the construction industry makes to the economy. This amounts to around 20% of GDP. However, the remainder of this paper will focus on primarily on construction as economically defined, but including parallel and upstream activities, totalling around 10% of GDP. [2]

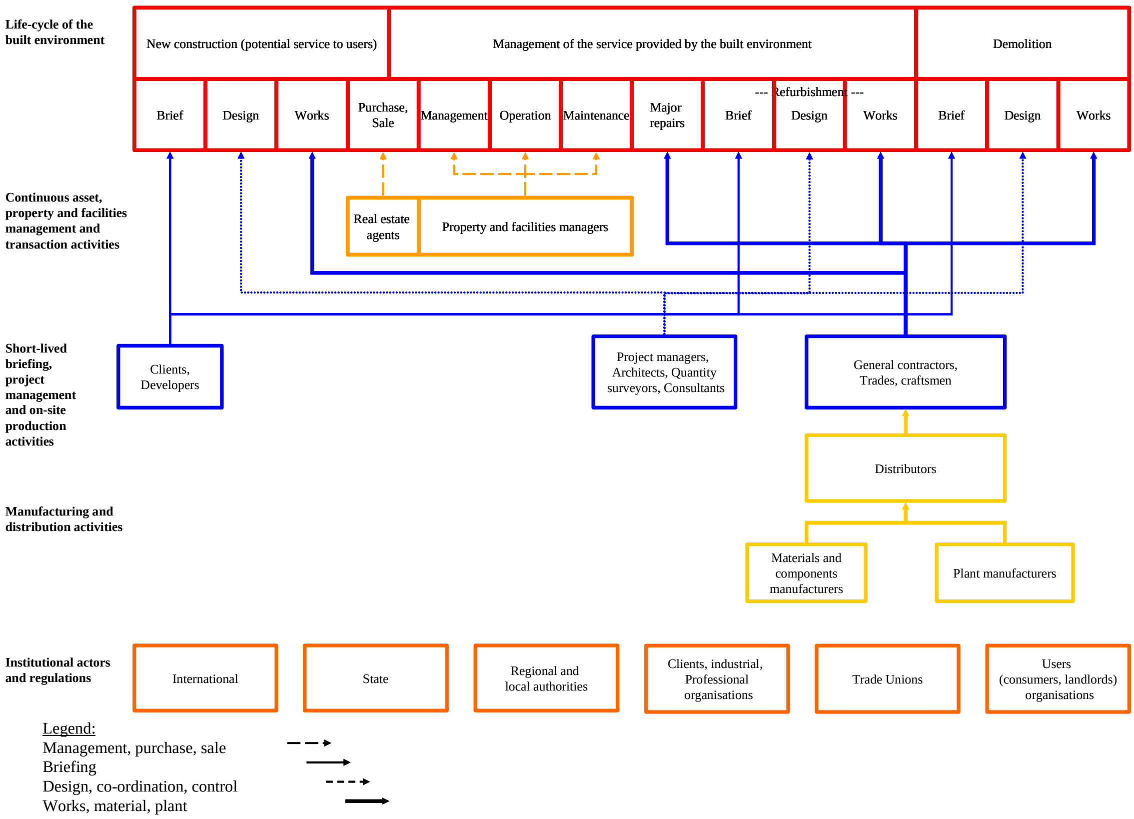


Figure 1: The Construction and Property Sector Framework (Source: Carassus, 2004)

In summary, the official economic classification of construction omits major intrinsic elements of the industry, such as designers (architects and engineers) and thus seriously biases analyses of the economic activity taking place. Still more serious it mentally separates the industry from the on-going societal experience of the built environment which is how much of the value of construction activity is realised.

A generic driver of more targeted and efficient economic activity, regardless of how it is officially classified, is innovation. This takes the form of new products and services to create and satisfy demand, and new process innovations to improve

[2] The Pearce Report [The Social and Economic Value of Construction. (nCRISP, 2004)] incorporates upstream and parallel activities in its broader definition of the sector and estimates the GVA contribution of this sector at 10%. The definition based on the construction sector framework, which incorporates property management and real estate activity means that the value of the built environment sector is closer to 20% as stated in the recent UK Construction Strategic Research Agenda.

efficiencies. A better understanding of the catalyst and nature of innovation in construction will give valuable clues as to where economic activity takes place and, in so doing, caste light on important pockets of 'hidden innovation.' This proposition is explored in the remainder of this paper.

2. The nature of innovation in construction

Working with industry practitioners, successful innovation has been defined as: *"the effective generation and implementation of a new idea, which enhances overall organizational performance."* (Sexton and Barrett, 2003: 626). The newness aspect differentiates innovation from change. All innovation implies change but not all change implies innovation. For a contractor, for example, a change in a materials supplier is not necessarily an innovation. However, a change in a relationship between the contractor and a supplier from a project-to-project open-tender situation to a long-term partnering type of relationship would constitute an innovation.

Construction is often portrayed as not being an innovative sector. Commentators have labelled the sector as being 'extreme conservative' (Rosenberg, 1982), 'low tech' (Reichstein, et al., 2005), and 'an industry of the old type (Landes, 1969). There are myriad characteristics of the industry that are consistently put forward as the 'cause' of this lack of dynamism and innovation. These can be distilled into three strands.

- First, the project-based nature of the industry is seen as constraining innovation. Gann and Salter (1998: 435) note that "the management of innovation is complicated by the discontinuous nature of project-based production processes, in which there are often broken learning and feedback loops."
- Second, the structure of the industry is seen to inhibit innovation. The UK construction industry is predominantly made up of firms made up of less that five people, who have limited capacity to innovate due to their management abilities, limited resources and reduced opportunities for supply chain driven innovation because of their inability to form long-term relationships with other firms (Sexton and Barrett, 2003).
- Third, is the adversarial culture of the industry which ushers in detrimental short-termism and opportunism manifest in procurement arrangements between project team participants. Indeed, it has been argued 'the construction industry is infamous for the barriers it places in the way of innovation' (CERF, 1998). This presumption is commonly embedded at a government level. The 'Egan' report, for example, expounds "that the UK construction industry will not reap the full economic benefits unless we identify the economic, legal, institutional and cultural obstacles to innovation, and do what are necessary to remove them."

The net effect of this maelstrom of opinion is that construction firms are commonly characterised as being conservative, risk averse, invest little in research and development, and look to suppliers to be the stimulus of innovation.

We contend that this perspective castes a false shadow, which hides the highly innovative aspects of the sector that are responsible for progressively enhanced levels of 'realised value' – demonstrated by the growing gross value added (GVA) of the sector (see section below). Further, this shadow is primarily caused by the way innovation is measured and modelled. We argue that the visibility of innovation activity in the construction sector is dependent on the type of innovation. Three types of innovation can be fruitfully discerned: 'sector-level', 'business-level' and 'project-level' innovation. Sector-level is the most visible type of innovation and project-level is the most hidden. These are described below.

2.1 Sector-level innovation

Sector-level innovation is very visible and often produces radical or step change. It takes two principal forms. First, *regulations and standards* which prescribe new sector-wide product or material attributes (for example, structural integrity) or new behaviours (for example, health and safety regulation) forces 'compliance' innovation (for example, see Sexton and Barrett, 2005). A current example of this is the new Code for Sustainable Homes (http://www.planningportal.gov.uk/) which is a phased regulatory framework to 'force' the industry to build 'zero carbon' homes by 2016. David Nuggett, a Director of Crest Nicholson PLC (a major UK housebuilder, recently reported that this requirement will require radical innovation in all aspects of the design and production process (Nuggett, 2007). Second, *dominant construction clients* drive radical innovation at a sector level, as well as for their particular needs. British Airways Authority, for example, took a leading role in driving the development and implementation of partnering for Terminal 5, which became the bedrock of the influential sector-wide Egan agenda.

2.2 Business-level innovation

Business-level innovation tends to be more obscure than sector-level, and can produce either radical or incremental innovation. The innovation focus is on general resource and capability development, rather than being project specific. There are two key types of business-level innovation. First, explicit *research and development* activity which concentrates, for example, on producing either radically new or incrementally improved materials, products or subsystems. This activity produces 'potential value' (i.e. it still needs to be commercially exploited) and is highly visible in the national accounts (see section below). Second, is the *general organisational development* activity which generates, for instance, radically new or incrementally improved supply chain arrangements, human resource management strategies, business processes or practices.

2.3 Project-level innovation

Project-level innovation activity is the most hidden, but arguably has the greatest impact on sector performance, and is generally incremental in nature. The co-production of novel design solutions between different parts of the design team (architectural, structural engineer, mechanical engineer, and so on) builds upon their respective knowledge and experience (for example, see the Corus case study box below). Similarly, the day-to-day problem solving on site during the production phase is very much grounded in participants' tacit knowledge and 'learning by doing.' The cumulated impact of incremental innovation overtime is significant, both at firm and aggregated sector level.

Corus mini-case study
Corus' *Living Solutions* provides design and production solutions of fully-fitted steel framed accommodation modules. The company transferred its manufacturing expertise from its steel operations to integrate computer numerical controlled equipment and assembly production to produce volumetric housing systems for the construction industry. At first, the firm struggled to properly understand the nuances of the construction market – particularly the lack of consistent design and production

processes compared to the manufacturing sector. *Living Solutions* failed to penetrate and gain market share. *Living Solutions* realised that business level innovation was insufficient in itself to be successful. Its solution to this was form a joint venture with Mowlem / KBR (major construction contractors) to access the tacit knowledge and networks of the sector, and to form a credible proposition in the market place. This joint venture was driven by the Ministry of Defence (a sector level, dominant client) £1 billion PFI redevelopment of Salisbury Plain barracks. The project team, working in close collaboration with the client, produced innovative project-specific steel framed solutions to satisfy the exacting MoD 'Z-standard' service level agreement. The project will maximises the benefits of offsite manufacture through the long-term production requirement of 145 buildings. It is envisaged that the long production run will also yield incremental innovation through day-to-day 'learning by doing' which will feed into design and production activity of other projects.

So, in summary, the sector has a poor image in relation to innovation. This poor image is grounded to a significant extent by how innovation is traditionally accounted for. Taking a broader perspective a range of innovation mechanisms at work within construction has been described. These range from sector-level actions that can lead to radical innovations, to project-level innovation that tends to be incremental in nature. In between business-level innovation mediates between the two through portfolios of radical and incremental actions. The multi-level, multi-actor, multi-phase nature of construction presents significant, if not insurmountable, challenges in measuring innovation performance in precise metrics. There is thus an urgent need for appropriate proxy metrics to generally illuminate the real scale and scope of innovation activity in construction.

3 Proxy metrics of hidden innovation

3.1 Construction specific

Expenditure on R&D provides a simple measure of the amount of resources that an industry dedicates to the generation of new knowledge. The R&D carried out in construction has remained low (0.25%) and relatively constant over recent years, but is actually falling as a proportion of overall UK expenditure on R&D. However, the structure of the industry means that it is highly competitive. Therefore, firms are continuously evolving new ways of working and new products in order not to fall behind. New firms enter and existing firms exit in a market model, driven by systematic innovation processes.

Thus, we would argue that the level of formal R+D in the sector is not representative of the work done to improve the efficiency and effectiveness of the sector as a whole. Despite the relatively low R&D component in the construction industry, KPI figures, for example, demonstrate improved year-on-year performance.. The sources of this improvement are often not clear, although we argue that a key par of this progress is achieved through "hidden innovation."

The DTI's Key Performance Indicators (KPIs) (Construction Statistics Annual 2006) make clear just what improvements the construction industry has achieved. The KPIs comprise three main areas – Economic, Respect for People and Environmental. Table 1 summarises the results for the more important indicators for the years 2002–

2006. Of the 40 indicators, over 30 have improved or stayed constant, showing a vast overall improvement within the industry. These improvements can be considered to be a product of a combination of incremental change, initially stimulated by phases of significant innovation. The 'partnering' innovation, for example brought about changes in client satisfaction and construction companies' profitability.

Table 1: KPI Statistics for Construction 2002-2006

KPI	**Measure**	**Performance**				
		2002	**2003**	**2004**	**2005**	**2006**
Economic						
Client Satisfaction - Product	Scoring 8/10 or better	73%	78%	80%	83%	84%
Client Satisfaction - Service	Scoring 8/10 or better	65%	71%	74%	77%	79%
Defects	Scoring 8/10 or better	58%	68%	68%	72%	77%
Profitability	Median profit before interest and tax	5.6%	5.8%	7.5%	8.7%	-
Productivity	Median value added / employee (£000)	28.0	31.1	32.6	34.2	38.2
Respect for People						
Employee Satisfaction	Scoring 8/10 or better	-	41%	41%	51%	55%
Environment						
Impact on the Environment – Product	Scoring 8/10 or better	-	28%	32%	53%	54%
Impact on the Environment – Construction Process	Scoring 8/10 or better	-	51%	56%	44%	45%
Energy Use (Designed) – Product	Median Energy Use Kg CO2 / 100m² gross floor area	-	4414	4295	4291	3729
Energy Use – Construction Process	Median Energy Use Kg CO2 / £100k project value	-	288	322	293	293
Waste – Construction Process	Median Waste Removed from site m³ / £100k project value	-	43.5	47.1	41.6	37.0
Whole Life Performance – Product	Scoring 8/10 or better	-	29%	35%	41%	41%

The KPI figures in Table 1 can be used to illustrate the three 'types of innovation' as outlined above. The KPI measures of client satisfaction, and a reduction in defects reflects the *project level innovation* that takes place due to evolutionary changes that occur on site in order to improve the day to day activities of a project. *Business level innovation* is also represented in the KPI figures for profitability, productivity and employee satisfaction. These have all increased due to businesses actively seeking better practices in order to enhance factors such as these as well as others. *Sector level innovation* also has an effect on the construction sector KPIs. In this context, it is mainly discerned as environmental effects, which have for the main part improved, much of this change is due to new regulations enforced upon the sector as a whole.

3.2 Construction in Context

Significant improvements in performance by the construction sector in recent years have been illustrated above. But how does this compare with other sectors? Taking a 25 year series, Figure 2 illustrates the relative improvements in Gross Value Added

(GVA) for three sectors, namely manufacturing, construction and services. It can be seen that the sheer relative growth of the services sector puts it in front, however construction too has a steady upwards trend, albeit with a boom period in the middle. Manufacturing lags well behind. So this would appear to indicate that the more recent improvements illustrated above, several of which are on soft dimensions, are built on a steady improvement that is evidenced in hard economic terms too. Further, this exceeds the improvement in contribution in manufacturing generally.

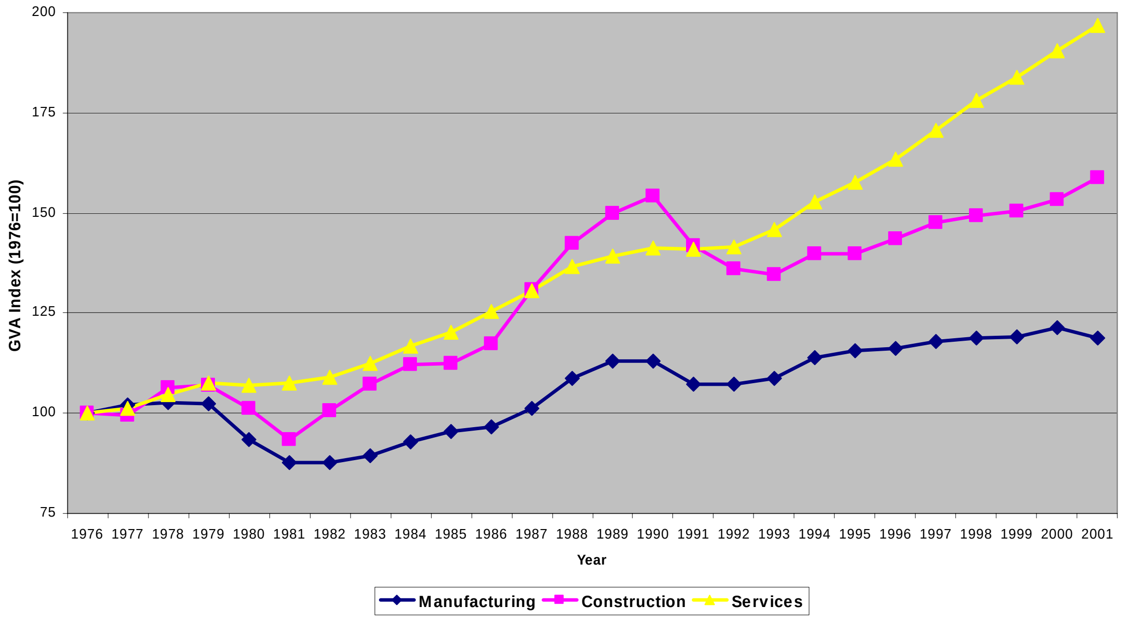


Figure 2: Relative GVA of UK manufacturing, construction and service sectors[3]

Given the broader conception of the industry given at the start of this paper, it is relevant to look to the areas adjacent to construction to understand the innovation context better. Using an input-output based indicator enables the separation of the technology generated by the industry itself through its own R&D and the technology acquired through purchases of services and materials. Interestingly the construction industry is a user of products and services from other sectors, which have some of the highest expenditures on R&D in the economy e.g. machinery and equipment (5.4%); technical testing and analysis (3.4%); telecommunications (6.7%)[4]. R&D expenditure in the UK construction sector was about £140 million pa in the late 1990's (of which higher education institutions undertook 55% and trade associations about 33%). If firms, whose output is mainly supplied to construction are added, the total comes to about £236 million. (Clark and Simmonds. 2001).

Conversely, much of the innovation in the closely related area of engineering and technical consultancy is dependent on client engagement in the context of specific projects. The consultancy sub-sector represents approximately 10 % of the total construction industry and engineering consultancies provide services for the total life

[3] Source: DTI "UK 2001 Census Statistics". HMSO, London, indexed from 1976

[4] Source: Expenditure on R&D performance in U.K. businesses. National Statistics, UK Business Enterprises R&D 2005.

cycle of client assets. As part of this work, firms have developed a wide range of bespoke tools and techniques such as modelling software, electronic data collection and risk assessment and prefabricated components. Engineering consultancies are not well-represented by measures such as the DTI's *Value Added Scoreboard* because they do not capture most of the value that they create. Generally it is passed on to the client unnoticed.

Total factor productivity (TFP) is a more broadly inclusive approach that provides a measure of technological progress. It refers to the change in output, when all inputs (labour, capital etc) are varied. Interestingly O'Mahoney and de Boer (2002) have carried out an international comparison on TFP for the construction industry (see Table 2).

Table 2: TFP (1999: UK = 100)

	UK	France	Germany
Economy	100	110	121
Construction	100	98	85

On this basis, the UK construction sector appears to be better positioned than other major EU countries, in contrast to the economies when compared as a whole. New investment in capital in an industry both updates and increases an industry's capital stock. This investment impacts on productivity through capital deepening and also the incorporation of new technology. Technological advances are brought into the production process and, provided that the environment supports innovation and workers are equipped with the relevant skills to take advantage of new technologies, investment in physical capital and new processes may lead to an increase in TFP.

However, the construction industry certainly is not amongst the foremost industries in its use of many categories of new technology but the significance of the efficiency gains from the use of new technology in the construction sector still needs to be understood. There has been concern for the last two decades that the construction industry has lagged behind other sectors specifically in its take-up of new technology. A survey of U.K. industry in 1990 (CICA, 1990) showed that, whilst the 1980s had been a period of rapid technological change, this did not result in major investment by the construction sector in comparison to a selection of other industry areas. In the period since that survey, concerns over the apparent inability or unwillingness of the industry to take advantage of new technologies still exist and the low level of expenditure by the industry appears to persist. From the U.K. Input-Output tables for 2002 (ONS, 2003), the percentage of inputs acquired from the Computer Services sector - based on the standardised OECD definition - can be calculated and a 0.4% level for the construction sector appears to indicate a degree of consistency, when looked at in conjunction with the 1990 survey. Table 3 allows comparison to be made between the construction industry itself and the closely related sectors of architectural activities and real estate. The latter sector, in particular, is one in which expenditure on ICT services has been an important feature.

Table 3: Use of Computer Services (by industry) 2002

Industry	%
Construction	0.4
Retailing	1.0
Architectural activities	2.4
Real estate and lettings	7.9
All industries	1.0

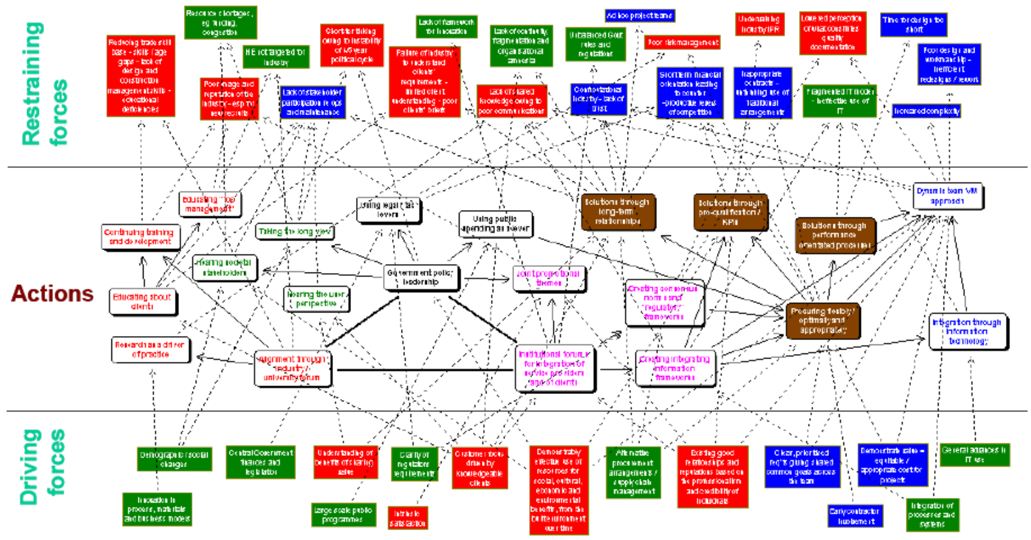
(Source: Derived from the U.K. Input-Output Tables 2003)

This reinforces the suspicion that the more highly innovative aspects of construction have tended to be defined out by the limited economic categorisations. It would be like saying car design was not art of the automotive sector!

In summary, UK construction shows a strong, sustained and improving performance on both hard and soft measures. This stands up well when compared with other UK sectors and construction in other countries. Investment in R+D, and say computers, has been relatively low within the narrow definition of construction, but taking a more holistic view the context provided by associated areas compensates to a degree. The fact remains, however, despite formal R+D expenditure being low, performance improvement is ongoing, indicating that 'hidden innovation' is strong.

4 Drivers and barriers to innovation

Based on a survey and workshops in five countries (United States of America, Australia, Canada, Singapore and the United Kingdom)[5], including the UK, a strong consensus was gained on the various driving and restraining forces for innovation in construction. A force field analysis is shown in Figure 3.



[5] See www.cibworld.nl/revaluingconstruction for further details of the Revaluing Construction initiative within the International Council for Research and Innovation in Building and Construction (CIB)

Figure 3: Synthesis map from CIB Revaluing Construction workshops

These broadly divide into three types, as below:

- Frameworks
  These are factors that provide the broader structural or organisational context
  - → Examples of restrainers are: lack of structure for innovation, limited land space for construction, lack of continuity and fragmentation and unbalanced government rules and regulations
  - → Examples of drivers are: government legislation, better processes, innovation in materials, population growth, email and ICTs and long-term relationships
- Knowledge / attitudes
  These are general factors, but those that attach to individuals
  - → Examples of restrainers are: poor image of construction, inability to manage or transfer risk, uninformed team members, training / education deficiencies, society conservatism and short-term financial client orientation
  - → Examples of drivers are: knowledgeable and focused clients, credibility / keeping promises, intrinsic satisfaction, emotional intelligence and demonstrable cost / value
- Project
  These are factors that collect specifically around the project phase
  - → Examples of restrainers are: system of lowest bidder, limited budgets and other parameters, inappropriate contracts, lack of stakeholder participation re operations and maintenance and "cut throat" competition
  - → Examples of drivers are: single point procurement, clear communication of needs and perspectives, shared common goals across the team, early contractor involvement and thorough programming and research in early stages

Significant problems became evident in the absence of stability and balance in *frameworks* that could take construction beyond the current position of stumbling from project to project, however, there are opportunities to build on, such as the over-arching demands of population growth and governments' focal areas of influence. Many of the constraints on progress are seen to be to do with the *knowledge / attitudes* of all those involved in construction and this includes their education, training and basic attitudes, however, where there are enlightened individuals these are seen as leverage points for progress leading to a collective orientation towards value and away from cost. 'Actions speak louder than words' and once a *project* is initiated the practical influence of the frameworks and attitudes described above becomes very clear in the prominence of the criterion 'lowest first cost' However, drivers for development are seen around the early involvement of contractors and the broader consideration of users needs, all within more mutually beneficial relationships.

The workshops identified actions that could exploit drivers and address restraining forces and these were organised by stakeholder:

- In the area of *"industry / client"* there was a broad range of proposals. In general it seems there are multiple drivers, many restrainers and a moderate number of linked actions. This profile suggests the realistic possibility of successful progress in this area.

- In the area of *"Government"* there were lots of proposals. There were many potential drivers as well as restrainers and linked actions, reflecting the perceived feasibility of this as source of movement towards improvement.
- *"Procurers"* made up the biggest listing. There was thought to be a reasonable foundation of drivers, quite considerable restrainers and very many linked actions. This appears to be an area that is quite generally perceived to be a leverage point for initiating progress.
- For *"project team"* there were only a few conceptual drivers, but many restrainers and linked actions, indicating the lack of a strong base from which to act. However, this is the one area in which IT arose, variously as an action, restrainer and driver.
- In the case of *"education and research"* it was clear that there are few direct drivers, many restrainers and a lot of linked actions. In other words education and research seem to be areas that can be of systemic importance, but they do not have a strong base in the construction sector from which to exert influence.

Overall it is clear that certain elements are variously available and can work positively in concert: the industry and clients can act together to improve the environment for improving the performance of construction and Governments in particular can be influential in terms of policy leadership and as a major client. At the more operational level procurers hold a key role that can significantly impact on how projects are set up. Linked to this there is considerable potential within projects to make progress, but this is quite dependent on the scope provided by procurement and other "upstream" actions. Education and societal perspectives are doubtless important contributors, especially taking a longer-term view; however, they are unlikely to be the main, immediate focus for driving improvement.

In summary, the Revaluing Construction work showed that these stakeholders operate at various levels as shown in Figure 4. The industry and clients can act together to improve the environment for improving the performance of construction and governments in particular can be influential in terms of policy leadership and as a major client. At the more operational level procurers hold a key role that can significantly impact on how projects are set up. Linked to this there is considerable potential within projects to make progress, but this is quite dependent on the scope provided by procurement and other "upstream" actions. Education and societal perspectives are doubtless important contributors, especially taking a longer-term view, however, they are unlikely to be the main, immediate focus for driving improvement.

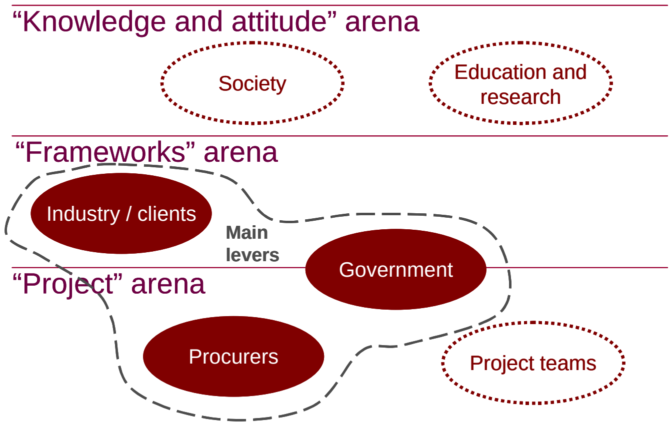


Figure 4: Summary disposition of stakeholders

Table 4 shows in more detail the actions that the groups can own, with the three main driving stakeholders first and the three more dependent areas second.

Table 4: Summary of major stakeholder groups and associated action areas

Stakeholder	Action area
Industry / client	Institutional forums for integration
	Creating integrating information frameworks
	Creating consensus "regulatory" frameworks
	Joint promotional themes
Government	Policy leadership
	Public spending as a lever
	Legal / tax levers
Procurers	Procuring flexibly / optimally and appropriately
	Solutions through long term relationships
	Solutions through pre-qualification / KPIs
	Solutions through process characterstics
Project team	Dynamic team / VM approach
	Solutions through progressive process
	Solutions through project information technology
Education and research	Educating about clients
	Educating "top management"
	Continuing training and development
	Alignment through industry / university forum
	Research as a driver of practice
Society	Hearing the user perspective
	Hearing societal stakeholders
	Taking the long view

5 Conclusions and Recommendations

The sections above have set out a variety of interconnecting factors:

- The construction industry is a huge part of the economy, be it 6% of GDP on the narrow economic definition, 10% if parallel and upstream activities are added in, or 20% if downstream activities are included. The logic of the latter is highlighted through the meso-economic / sector approach which stresses the importance of orientating activities seamlessly towards the ultimate user.

- The negative image of the construction industry was then assessed as a "low tech", "conservative" sector. This counter-productive categorisation of the industry was challenged as was the inappropriateness of the usual measures used for innovation that are blind to the nature of project based innovation that is widespread in construction. Three types of innovation activity were introduced and illustrated, namely: sector-level, business-level and project-level. A trend from radical to incremental change was suggested across these levels.

- The contradiction was presented of the low level of formal R+D in construction and evidence of progressive improvement in performance, on both soft actors and in hard economic terms. This improvement was favourably compared with other UK sectors and other construction industries abroad. So, how can this be? To some extent it was suggested that the innovation environment provided by related areas was more positive than was immediately obvious, but it would still seem that "hidden innovation" must be taking place that is missed by current analyses.

- Lastly, the drivers and barriers to innovation in construction were assessed and it was highlighted that various stakeholders had differing potential to drive change, operating in three broad arenas. Leading clients and industry players, together with Government and procurers could drive radical change in the "frameworks arena" and "project arena", but project teams can only really achieve incremental change without this lead. In the "knowledge and attitudes arena" there are few drivers, but change originating elsewhere can be facilitated or consolidated, in the longer term, by action here.

So, how does this all come together? Figure 5 shows a speculation on the split between Sector, Business and Project level innovation.

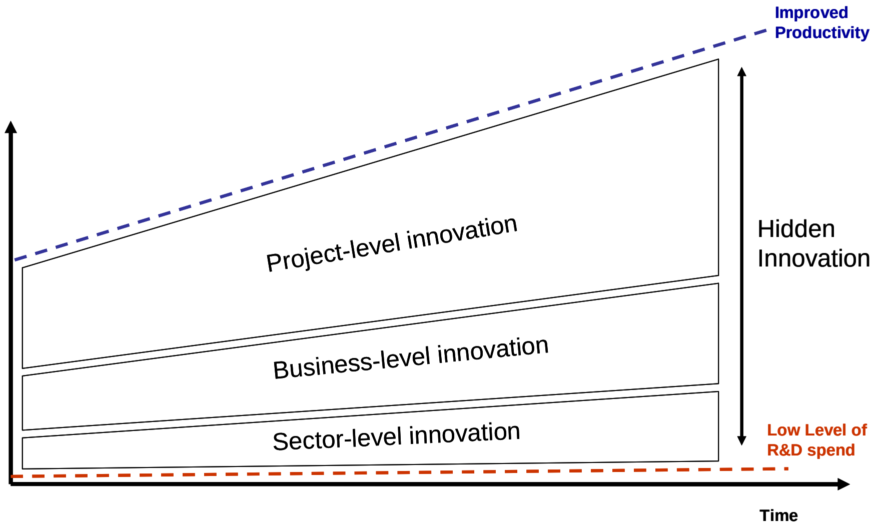


Figure 5: Hidden Innovation in the Construction Sector

Considering the project-based nature of the industry, it is suggested that the major part of "hidden innovation" must inevitably lie in the project-level area. However, the various strands of innovation will clearly interact. One way of seeing this is to think in terms of a base level of innovation at the project level, driven by a combination of the inherent problem-solving nature of construction work and the highly competitive market conditions construction companies experience. This innovation will tend to be incremental, but if, say, major clients / procurers move to change structural characteristics then more radical change becomes possible and could be exemplified by framework agreements leading to significant innovations in information flows and investment in new technologies. Connected to this, if those involved are trained / educated, or simply regularly exposed to good practice, then the business level innovation will accelerate and more reliably consolidate. Further, the confidence and competence of those involved to attempt radical change will be enhanced.

It is proposed, for long-term, progressive improvement through innovation, that all three elements are needed. Then, taking a systems view, the innovation ecosystem will be generally enhanced by more conducive structural conditions, more capable companies and improved innovation at the project level, leading to greater confidence for key stakeholders to innovate, so creating a virtuous cycle.

This paper started out with a formal, abstract, economic view of construction and then tracked both economic and satisfaction measures of performance. This led to consideration of a mix of innovation types ranging from national initiatives to local, informal collaborations. Standing back the picture can be more clearly seen as one where formal initiatives to achieve step change are important, necessary, but not in themselves sufficient to maximise progressive innovation. However, conversely, hidden innovation will be constrained to a level of incremental change unless major contextual limitations are removed. The locus of innovation is ultimately the firm, which must grasp local project opportunities, but fashioned within the broader sector context. The innovation ecology is systemic and to make progress it should be addressed in all its richness.

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