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Construction in Transition: Where Are We, and Where Could We Be?

Ronald McCaffer
Professor, Department of Civil and Building Engineering
Loughborough University, Leicestershire, UK

Francis T Edum-Fotwe
Research Fellow, Department of Civil and Building Engineering
Loughborough University, Leicestershire, UK

Abstract
The magnitude of transition in construction is explored through a chronological charting of dominant managerial and allied developments that influenced improvement efforts in sector. This shows a shift from a site focus to corporate and sector-wide initiatives including emerging influences of sustainability and a re-definition of professional roles. Some current issues that are being addressed through improvement efforts are presented and potential futures also discussed.

Keywords
Construction Sector, Improvement, Design, Production, Management, ICT

1. Introduction

Global economic competition has compelled many organisations to pursue a path of exploring all possible options for achieving greater effectiveness and efficiency in the delivery of their products or services (Drucker, 1994). The availability of support technologies for such continuous productivity improvement is shifting the emphasis of this required competitive improvement from physical activities and materials to include attendant *latent* people related-factors. Up until the turn of the last two decades these latent factors had played a lesser role in the focus of improvement in the sector. For example, it is no longer sufficient to simply deploy technological tools to achieve factor productivity as this only helps to provide increased volumes of ineffective services or products. Many construction organisations are waking up to the untapped potential of the work-force as the primary distinguishing factor in organisational performance (Cooper et al., 1998). The gradual emergence of the knowledge age, which recognises construction professionals as the very embodiment of organisational knowledge assets presents clear evidence of the changing scenes in construction (Edum-Fotwe and Thorpe, 2002; Gregory and Deasley, 2002). Such a shift gives rise to a number of critical issues that construction may have to address in the present and future both at organisational and sector level. Consequently, the face of construction today in one sense could be described as being markedly altered from how it used to be two decades or so ago. A decade ago, the beginnings of such a shift was identified by McCaffer (1990; 1993) for professional careers in construction. In this paper the authors attempt a reflection of the journey of this transition by looking at how construction has changed over the last four decades to the current status of the sector. In the particular, the analysis of the 'now situation' should help to highlight some of the issues facing construction and for which efficient resolution could bring about significant progress for the sector.

Equally, the trends of change in the different epochs of construction provide an indication of the direction in which the sector may progress into the future. The discussion on improvement trends concludes with suggestions of such a future direction for the construction sector.

2. Construction – A Fragmented Conversion Process

Figures 1and 2 present conceptual models of construction covering respectively the design and site production phases that make up a typical project. The two figures together depict construction as a conversion process that involves several suppliers and requires careful coordination and integration. At the design phase (pre-site production) the factor of conversion is essentially information. The inputs A, B, …, E and the outputs W, X, …, Z entail information detailed in different formats and media. This clearly makes the design phase of construction an information transaction activity or knowledge-based endeavour.

Figure 1. Model of construction – the design phase

Figure 2. Model of construction – the production phase

The output from Figure 1 serves as part of the input for the production phase in Figure 2. The conversion process of translating inputs to generate outputs is driven by *skills*, *knowledge or know-how*, and appropriate organisational and managerial *systems* that facilitate their integration. These factors reflect what is generally described as *soft* and their performance is less amenable to the simple input-output productivity analysis that tends to characterise the production phase depicted in Figure 2 (Checkland, 2000). The production phase on the other hand lends itself to such input-output evaluation. The inputs (A1,…, E1), outputs (W1,…, Z1) as well as their conversion involve physical and tangible resources beside the intangible knowledge resources. The tangible aspect of this phase makes it relatively easy to define productivity measures to assess discreet *activities*, a series of activities making up an *operation* or several operations coming together to form a *process* in the production phase. The significance of this ease of applying input-output analysis to the production phase has been a focusing of improvement efforts at the production phase, with obvious accelerated benefits (Flanagan et al., 1998). While the design phase has equally witnessed some notable developments such as CAD, the take up of opportunities offered by these developments have often fallen short (Battersby and Yates, 2003). The effect has been a relatively slow growth in the improvement of systems and knowledge-related aspects of implementing construction projects especially where such capability already exists. The rather slow take up for such capabilities has been associated with a lack of or inadequate consideration for the *soft* end-user requirements in such developments for construction and engineering (Checkland and Scholes, 1990).

The models in Figures 1 and 2 also capture the essence of fragmentation between *design* and *production* phases in construction. Whilst integrated forms of procurement such as design-and-build and PFI have been explored or in some cases extensively implemented within construction, theses are predicated upon the *separated principle*. Essentially, a design solution is generated and then some thoughts are given to its production after the design has been approved (Kuprenas, 2003). While there is evidence of a growing reliance on buildability or constructability input by contractors during the design phase, the solution appears to lie in the integration of the two phases (Cooper et al., 1998). Such integration will facilitate the transfer of the essence of improvement in the production phase to the design phase, as well as the converse. In the past construction organisations were viewed as entities whose inner workings could not be observed, and whose actions could only be understood by *reviewing* their post-hoc responses to the external business environment. Research and development effort coupled with academic industry collaboration has helped to bring about a better understanding of the operational activities that form the internal workings of these construction organisations (Harris and McCaffer, 1995). However, understanding such internal operations presents little value unless it results in a more efficient implementation of future operational activities. The next section looks at areas of such improvement effort for the production phase. These areas often formed the focus of academic research at different times over the last four decades (McCaffer and Edum-Fotwe, 2001).

3. Improvement Effort and Transitions

The evolution of improvement efforts within construction has often been advanced to address the production phase. While some of the thematic issues on improvement equally addressed the design phase, the primary drive for their uptake was provided by the production phase. Over the past four decades the construction sector has experienced significant transformation in the way its projects are managed and its business activities undertaken. This is driven largely by changes in competition within the sector primarily from the production phase because of the exceptional focus on cost as a discriminant in project selection. Some of these practices are finding their way into the design phase. The various themes that have progressively contributed to this transformation can be associated with different periods. It is important to bear in mind that while the categorisations adopted by the authors reflect defined chronological boundaries, in practice, the periods extend on both sides of the timeline, with the dominant development reflected in the particular sub-section.

3.1 Site operations

Improvement efforts during the 1960s and early 70s were focused predominantly on *the construction site*. To expose the inner workings of the organisations, research effort within construction management in this period concentrated on understanding and explaining site operations, which often presented easy cases for observation and was also perceived as rather inefficient (Ministry of Public Building and Works, 1964). The applications of *work-study techniques* to site operations advocated by Harris and McCaffer (1977), Calvert (1970), Oxley and Poskitt (1987) and others provide typical examples of research effort in construction undertaken to shed a greater understanding on the nature of site operations. Modern planning of construction projects became established in this era. This was motivated by developments in manufacturing and led on to improvements in the structure of site operations, which in turn helped to highlight the need for various functional roles and their support to and inter-relationship with site operations. In particular, the need to provide greater accuracy in the estimation of cost and time for projects as a result of economic pressures became apparent. These pressures continue to today along with efforts to drive improvements.

3.2 Functional activities

The mid 70s and the 80s saw a shift from own-labour to labour-only subcontract arrangements. This was motivated by the need to develop a lower cost base for their activities in order to remain competitive, and this had profound impact on the structure of both the sector and companies. For example, at the sector level the responsibility for training of requisite skills shifted from major corporate organisations with a larger financial capacity to smaller enterprises with limited scope for taking on the added responsibility. The resulting decline in the number of skills within the sector has followed a consistent trend (DTI, 2002). At the company level this brought about a change in management and working practices at functional level (Finniston, 1980). For example the working practices in estimating changed from first principles to aggregating subcontractor quotations (Abdel-Razek and McCaffer, 1987). This change, while it helped to address the objective of a lower cost base, was also attended by an alteration in the role of the professionals that provided the various functional inputs such as estimating. Equally, the use of planning techniques that overcame the deficiencies of the simple Gantt chart had similar influences on the management of projects.

At the time of these structural changes computing facilities at corporate level was provided by the mainframe. These large machines were operated with bespoke software to address typical functional activities such as estimating, production programming and project accounting as well as central office functions. The emergence of the micro-computer at a later date brought about a transition in the scope and range of functional activities in the sector and consequently the make-up of the requisite skills for professionals. In particular, the introduction of micro computers saw the reduction in the mundane activities associated with the various functions, for example the many computations that estimators had to undertake. This was made possible with the availability of generic software tools such as spreadsheets and databases at the desktop level.

Also in this epoch is the quality initiative, including developments in quality assurance and total quality management (Juran, 1979; ISO, 1986; 2000). This initiative brought about a step change in the concept of the improvement agenda for sector, with attendant productivity attainments as organisations strove to attain and maintain client required TQM accreditation.

3.3 Project Perspective

The mid 80s to the early 90s witnessed a focus on the project, with the improvement efforts in the earlier periods above being translated to the level of the project. This was dominated by the widespread introduction of prototype IT applications and non-IT based models for direct use organisations within the sector. In many cases there was divergence between the claimed performance of these prototypes and real life, leading to much frustration for both organisations and individuals within the sector. Among the reasons for the inadequacies of the available prototypes were the following characteristics:

- Data captured for developing the prototypes is often insufficient, and lacking in accuracy.
- Communication between the developers and practising engineers/managers is not often effective.
- The prototypes often reflected only *hard factors* of the phenomena that they replicate.

As such, the use of these prototypes in practice proved difficult, and this coupled with the often tedious and long procedures they involved, along with the requirement of considerable *expertise* for their effective the use weakened the efficacy of these solutions. The emergence of *Expert Systems* and other *Artificial Intelligent Systems*, which in many cases relied on the then fledging IT revolution of the mid-80s was a natural reflection of the deployment of these techniques. This gave rise to the development and proliferation of construction specific computer packages to enhance the processes involved in managing projects. A major contribution of the use of IT in this way to facilitate the construction project was the emphasis it gave to the process in each function. Most of the solutions that emerged in this era addressed single activities, for example plant selection for earthworks. The results of combining isolated and independently derived optimal solutions for the various functional areas often produced a less than optimal outcome for the project.

3.4 Process and System Orientation

The early to mid 90s was characterised by a holistic perspective for project improvement efforts driven in part by the sub-optimality of combining independent optimal functional solutions that make up the project. The holistic standpoint was based on the concept that the project, like any other production activity, is a process. As a consequence, the effective improvement of the project process required an outlook beyond each of the isolated activities that make up the project. This naturally called for a *systems approach*, which enables the modelling of complex and large-scale activities. This is achieved by applying systems principles to aid a decision-maker with problems of *identifying*, *reconstructing*, *optimising*, and *controlling* a system (usually a socio-technical organisation). This involves taking into account a multiplicity of objectives, constraints and resources (Checkland, 2000). The underlying principle is to specify possible courses of *action*, together with their *risks*, *costs* and benefits for the project process. Thus, by considering the system as a whole, rather than individual components, the *systems approach* provides direction as to the optimal solution for the overall project. With its origin in the biological sciences, the systems concepts include *system-environment boundary*, *input*, *output*, *process*, *state*, *hierarchy*, *goal-directedness*, and *information*. This reflects the representation of construction project depicted in Figures 1 and 2, and makes the systems approach apt for addressing many of the management situations within the sector. The growth in the number of systems-related programmes in academia, mirrored by job positions in various industrial sectors, from the 90s is symptomatic of the relevance of this concept to modern complex managerial problems in organisations.

3.5 Construction as Business

The mid to late 90s was made out by the recognition that construction organisations are businesses that must not only undertake their processes efficiently, but also be in the right business in the first place in order to succeed. The Technology Foresight Programme (1995) for example provided a catalyst for construction to see its processes from this business perspective. Subsequent developments, such as Egan (1998) and its Latham (1994) forerunner, adopted the view of a *customer or client is king* focus, with recommendations for improvement in the value derived by the client. This was a consequence of domestic competition and emerging economic realities from increasing globalisation. The arrival of various Benchmarking schemes including the ECI Performance and Process Benchmarking Initiative provide appropriate channels for attaining such business and organisational improvement. The concomitant Key Performance Indicators (KPIs) from the Construction Best Practice Programme, and the Movement for Innovation (M4I) were aimed at spearheading a nationwide improvement in the sector. The impact of these initiatives, along with developments that have continued from them, has been a new way of doing business in construction. For example new forms of contract, such as two-stage design and construct, contract management, private finance initiations- PFI (or its root form of public private partnerships- PPP) are fostering a new business climate for the sector (HM Treasury, 2000). These changes are contributing to a re-definition of the roles and positions of key stakeholders within the sector. For example there has been a gradual shift observed in role of the architect, which had hitherto been a *lead* for the project team in the building sub-sector of construction to *concept guardian*, with the administrative lead role subsumed by other professionals (Edum-Fotwe and Thorpe, 2002). Equally observable is the growth of supply-chain principles in the sector, spurred on by a need to bring about better alignment of the various supplier organisations that provide inputs to the project. While initial efforts on this front addressed the physical logistics, later developments saw the inclusion of information resources in this improvement initiative.

3.6 Soft and Human Systems

From the start of the 2000s the issues that have driven improvement efforts in construction can be categories into two: *hard* and *soft* factors.

The *hard factors* refer to the mechanical operations of planning, scheduling, estimating and controlling. Improvement efforts on *hard factors* are easier to undertake and tend to dominate the overall improvement agenda within construction. It is argued that the domination of the hard factors in construction can be explained by the fact that construction is an offshoot from engineering. Its development and research in the past has therefore been influenced by its engineering tradition.

Soft factors on the other hand reflect behaviour, attitudes, learning, and communication styles, and derive essentially from the social sciences. It forms an area that is less understood and investigated in construction. The increasing recognition for the relevance of these factors to the construction project, organisation and industry has led to a growth in teamwork and partnering both at the project and company level. The call by Egan (1998) *in Re-thinking construction* and subsequent reports including *Accelerating Change*, can be seen as essentially marshalling these soft factors in the industry to ensure the recommended level of improvements (Egan 2002). Figure 3 shows how these soft factors are associated with tangible improvement in the prospects of corporate establishments within the construction sector by Re-Thinking Construction Forum.

Figure 3. The relationship between soft factors and improvement in construction (*Egan, 1998*)

This includes a greater collaboration along the project supply-chain, a business aspect that embodies the intangible elements of trust, openness, close relationships between clients, contractors, subcontractors, suppliers and all other stakeholders in construction. The soft orientation places greater relevance on such issues as judgements and intuition, as essential elements of professional capability, and thus places a high value on the contribution that people issues make to construction. The endorsement of this human asset outlook by the Movement for Innovation emphasises the recognition of this soft orientation (M4I, 2000). Equally, the emergence of knowledge management, a systematic approach for organising and utilising the *know-how*, *memory* and *intuitive capability* within an organisation, presents a shift from the physical assets to a combined physical and knowledge assets (Malhotra, 2001).

There have been instances of *knowledge accounting* systems implemented by some organisations. The potential of this development is huge and would result in fundamental transformation of the value system that underpins the activities of the sector.

4. Current Focus of Improvement

The earlier initiatives aimed at enhancing the performance attainable in the implementation of construction projects has continued to the present. These efforts can be observed in current developments that include:

- knowledge management
- process alignments and streamlining
- cost optimisation through elimination of non-value adding elements and more accurate estimates
- design management (for example ADEPT – Austin et al., 2001)
- systems engineering
- application of the TQM to additional areas (intangible aspects of construction)
- developing alternative forms of contract (including non-adversarial options such as partnering and alliance, PPP)
- the changing role and composition of sub-contractors
- changes in construction methods through pre-assembly and standardisation
- multi-skilled workforces and team working
- distributed working at the pre-production phase (allowing specialist anywhere to combine to offer better services)
- emergence of non-corporate virtual *communities of practice*
- improving legal arrangements
- developing more compatible soft and hard technological solutions
- use of the WEB architecture as a backbone for corporate and project communication

Notable issues giving rise to these current efforts include the changing organisation dimension for construction enterprises, and the possibilities presented by, as well as the constraints posed by information and communication technologies. These are discussed further in following sub-sections.

4 .1 The organisation dimension

Recent workplace innovations of a general nature such as employee involvement and empowerment, has resulted in greater recognition that workers at all levels of the organisation are a significant source of creative thinking (Kotter and Heskett, 1992). Consequently, the traditional division of work between *thinking* (white collar) and *doing* (blue collar) is gradually melding, requiring all workers to become part of an organisation-wide collaboration process (Leimeister et al., 2001). Equally, the presence of project-oriented consortia and short-term alliances in construction often means projects must be undertaken using a distributed work arrangement because of stakeholders who may be dispersed in different geographical locations. Edum-Fotwe and Thorpe (2002) provide a more detailed discussion on the emergence of such different distributed working methods that are becoming commonplace in construction. Construction and engineering organisations are increasingly looking to these collaboration efforts to make the design aspect more a part of the supply chain by doing away with design as a business-process *silo* and getting the company's designers and its suppliers working together. For example many global-oriented organisations in construction are trying to create an approach to design and production that can be described in terms of *design anywhere*, *build anywhere* in order to achieve greater efficiency.

4.2 The technology dimension

Figure 4 shows a diagrammatic representation of the transition in ICT for construction presented by McCaffer and Hassan (2002). The organisation archetypes depicted in the progression by Figure 4 is predicated upon effective and efficient systems that formally address the integration aspect required in construction.

Figure 4. Construction ICT transitions (*McCaffer and Hassan, 2002*)

According to McCaffer and Hassan (2002), although a certain degree of integration already exists between some information systems within construction' organisations, there is still a need for more integration with other information systems – essentially a call for interoperability. They concede that it is not practical to expect complete compatibility between all information systems however there should be more focus on standardisation of interfaces between the different systems. They argue that ICT tools should be able to exchange digital information with other applications/systems using appropriate data exchange standards. They also highlight the need for more utilisation of existing data exchange standards such as STEP and EDIFACT as currently contractors rely on exchanging information using neutral file formats and native file formats. Neutral file formats are mainly used in exchanging information of drawings (CAD), invitations to tender, text processing and banking and accounting. Native file formats (e.g. Microsoft Office products, DWG, HTML for web technology) are mainly used to exchange information of drawings (CAD), statistical calculations (spreadsheets), estimating and virtual reality (using web technology). The emergence of generic collaborative tools at both enterprise and project levels address a significant number of the constraints identified by McCaffer and Hassan (2002). The major constraint persisting for the construction sector is the relative lack of interoperability of the different offerings available. This is being addressed at worldwide level through the Industry Foundation Classes (IFCs) that provide a bridge across the different software vendors.

The main benefits of the change brought about by IT are speed and virtual proximity, two critical elements essential for achieving success in managing construction projects. Large volumes of data can be processed faster, and distributed to disperse geographical locations much quicker (Doom, 2001). This creates a virtual proximity for distant geographical locations and has resulted in a closer world. The developments for construction have almost exclusively taken advantage of innovations achieved in other domains, and as such have moved at a pace behind IT sector. The challenge for construction however, goes beyond producing engineers who are simply computer literate and can therefore deploy the technological innovations developed by the IT sector. It calls for engineers and professionals who are astute in their areas of specialisation and equally competent to devise the IT-based innovative solutions that will address the industry's operational weaknesses from a construction standpoint.

5. Emerging Issues

In addition to the current efforts and developments in construction, there are two key aspects that potentially could bring about a major shift in the workings and structure of the sector. These are the changing role and status of professional within the sector, and the growing attention given to sustainability and green environment issues. Each of these is discussed below.

5.1 Changing role of construction professional

The growing reliance on technology as a replacement for the mundane and repetitive operations in construction, especially during the pre-production phase is bringing about a shift in the traditional role of engineers and other professionals. The availability of computer-based alternatives is in some cases rendered the role of the engineer as the only knowledgeable person capable of establishing engineering solutions for the industry less significant. Currently there are software options that provide a walk-through experience for use by non-technical persons to exercise some of the decisions of the engineer. This development is likely to grow into the future as in many cases the software serves as an aid to practicing engineers as well. The essential difference in the use of such software will be the exercise of professional judgement, an area that will help engineers not only to maintain their reputation, but also to propose relevant solutions consistent with economy, quality and their environmental context.

5.2 Sustainability

The growing awareness of the impact that the built environment has on global warming as well as the depletion of limited natural resources deployed in the construction sector is raising attention on the sector taking more responsibility for the engineering solutions they propose. Within the UK such a *responsible engineering* agenda has been encouraged by the Environment Agency through the use of environmental impact assessment undertaken on most major construction and engineering projects. More recently, a sustainability agenda has been promoted in the UK through the activities of the Construction Best Practice Programme initiated after the Latham Report (1994) to ensure a better quality of life for everyone now and for generations to come through:

- social progress that recognises the needs of everyone;
- stable levels of economic growth and employment;
- protecting and enhancing the environment; and
- using natural resources prudently.

The agenda is underpinned by the three broad themes of environmental, social and economic accountability for construction projects. There is the need for awareness of such sustainable themes to be reflected in the training and academic development of the future engineer. This will ensure that engineering solutions proposed for the construction industry incorporate in a *strategic* way these environmental considerations, and not as an *after-thought*.

6. Where Can We Be

While the current efforts on improvement in construction have yielded considerable advancement in the sector, the full potential of the available systems and technologies available are often not exploited. A case in point is the use of ICT tools for design, whereby only a small set of the options available in most application software is exploited. There are a number of constrictions that account for this sub-optimal exploitation of the improvement potential that is available to the sector. These include the overly functional orientation within the sector coupled with the fragmentation of the project. The slow adoption of a process approach for implementing projects to overcome this fragmentation and functional orientation is beset by requisite skills to support their adoption. The contribution of requisite skills and know-how within the sector is driven by two forces, academia on the one hand and professional associations on the other. The aspirations of these two interest groups often converge, there are instances of divergence. For example, while the professional associations recognise the need for skills and knowledge renewal and strive through continuous professional development (CPD) to address this. This emphasises the growing need for a construction professional that undergoes periodic renewal of skills and re-training, and calls for academic programmes that provide periodic re-entry routes for professionals.

6.1 Defining a future agenda

The evidence from these improvement efforts combined with extraneous developments point to a future construction sector that could better exploit more efficiently the current potential of available technologies and systems. These developments include the following:
in would have

- More multi-skilled / re-trained staff, with periodic retraining being the norm.
- Skill levels will rise for some professional although these would be smaller in number as most professional roles become more routine in outlook
- More mobile workforce as the sector across different countries and regions converge, examples being NAFTA, EU, ASEAN.
- Integration of whole lifecycle of the project supported by a systems approach
- More pre-assembly/ automation/ standardisation of products
- More standardisation of design to allow designers more time to innovate
- There would have been considerable alignment of the interfaces in software and hardware as well as work processes, people materials.
- In particular, there would be considerable invasion of the production site by ICT through pervasive and emerging grid technologies
- ICT would be used as a medium instead of the supportive tool that it currently serves and facilitate virtual access to design knowledge globally at face-to-face speeds (Olofson, 2001).

These developments can be accelerated through a number of actions by the various stakeholders within the sector. These include a multidisciplinary outlook, and industry academia cross fertilisation to support both training and research, as well the widespread deployment of a soft systems approach.

7. Conclusions

The nature of construction from the sixties reflects a marked shift as a result of progressive improvement efforts that have addressed different aspects within the sector over the years. It appears that many of the earlier efforts of improvement in construction have attained maturation. For example, there is very little evidence of the earlier work study efforts facilitated the understanding of the content of work in construction. This has been replaced by a benchmarking approach to driving improvement.
The rapid rate of knowledge advancement within the last four decades has resulted in a situation whereby the boundaries of various subject disciplines are extending beyond their traditional confines. As a result, a wider appreciation of construction management beyond the traditional professional requirement is increasingly becoming important for the construction manager of today. This has been exacerbated by the

exponential rate of change of technological possibilities that are helping to re-define the roles of professionals and the nature of construction work itself. It is conceivable that effective exploitation of these technological and managerial tools can usher the sector into a fully fledged *grid* environment beyond the networked virtual options currently available. Clearly, academic research can facilitate the development of such a future for the sector through carefully focused investigations and developments. However, the availability of any such possibilities would not automatically translate to widespread adoption unless appropriate mechanisms are devised to ensure a continuous re-skill of the sectors employees.

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