Culture as a Component of Complexity in Construction

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Abstract

Both culture and construction have been suggested to be complex – culture as relating to, even governing, human behaviour and construction as a context in which human activities occur in the design, production, occupation, and use and disposal of major artefacts: buildings and infrastructure. Indeed, construction has been subject to various definitions and categorisations of complexity to assist analysis of the processes employed in the realisation and use of its outputs; including consideration of managerial and technical complexity. Historically, intuitive understanding of what constitute complex construction projects was supplemented with naïve objective measurements – such as the proportionate cost of building services. However, such approaches have failed to be very helpful in gaining understanding of the relationships between inputs to the realisations, the transformations within the processes and the resultant performance outputs. Following on from chaos theory, the emerging field of complexity theory, with its emphasis on linkages within systems and the ‘softer’ elements, has significant potential for providing insights. Hence, this paper examines culture in the context of and application to construction organisations and projects using the perspectives of complexity theory towards helping to determine a more detailed research agenda in the hope of gaining significantly greater understanding through this paradigm.

Keywords: complexity, culture, performance, systems

1. Introduction

A common caricature of something that is complex is that many component parts are incorporated and the links between those components are numerous and intricate. That description suggests that things which are complex must be systems. Components may be similar or extremely diverse in their properties and actions within the system, and the linkages likewise. What tends to be required for the presence, and extension, of complexity is many, possibly divergent, interdependencies between the components, potentially extended by diversity amongst the components themselves. That concept is reminiscent of the investigation and findings of Lawrence and Lorsch (1967) concerning differentiation and integration – as division of labour/specialisation increases, the need for, and difficulty of, integration multiplies; hence, the concerns over performance debilitation of construction through fragmentation (see, e.g., Latham, 1994; Egan, 1998; Construction Industry Review Committee, 2001).

Complexity is part of our lives and so, people adopt norms for levels and types of complexities which are encountered to yield ready classification of systems into simple, normal and complex. Thus, certain tasks are (virtually) always simple (e.g., drinking a glass of water) whilst others are complex (e.g., producing an aeroplane); many, however, are contingent upon what is available for use and the circumstances. In construction, norms of complexity depend upon the functional use type of project and the prevailing nature of the local industry – one guide is the cost significance of producing any given constituent of the project, encapsulated as whether it must be measured, or 'measured separately', according to the appropriate 'standard method of measurement'.

Thus, complexity is associated with high cost, together with requiring longer time for the process required to complete the product/output and, usually, greater attention necessary for achievement of the requisite quality. Complexity implies risks and (potential) problems – notably, 'wicked' problems which, by definition, do not have programmable solutions and so, require individual attention and analysis.

A conventional systems approach adopts the logic of Newtonian reductionism in which understanding is achieved through deconstructing the system into components which can be analysed individually. The results of the analysis of each component's behaviour and its outcome are, then, reassembled, often additively, to yield the total system and its predicted behaviour and outcome – such as in critical path programming of construction projects. A further step in such systems modelling is to introduce measures of probability (as in PERT), and, then, to incorporate probability combination effects at 'merge events' to yield a more realistic model of project duration requirements and dependencies (critical path(s), sub-critical paths and criticality indices for paths). Although still compliant with reductionism, the progression of approaches moves from simplistic determinism to stochasticism in analysing and predicting project durations, although synergy/holism remains unaddressed.

2. Complexity

Axelrod and Cohen (2000: 15) distinguish complicated systems, which comprise many components (such as those noted, above), and complex systems, which comprise "parts which interact in ways that heavily influence the probabilities of later events" or/and current events. Commonly, complex systems exhibit emergent properties. Emergence concerns simple rules yielding patters in the system as a whole and relates to both synergy and holism. Anderson (1999) notes that "Complex systems change inputs to outputs in a nonlinear way because their components interact with one another via a web of feedback loops". "Complexity Theory states that critically interacting components self-organize to form potentially evolving structures exhibiting a hierarchy of emergent system properties" (Lucas, 2004).

Given that definitions of complexity are many, and somewhat varied, and associated concepts include chaos, complex adaptive systems, complex evolving systems, and dynamic complex open adaptive systems, Lucas (2005) distils the characteristics of complex systems to be autonomous agents – components of the system can act on their own; nonlinear relationships (links between agents) – due to the feedback loops; and non-uniform parts – occur as agents and relationships may vary throughout the system.

In examining complex systems, systems theory is combined with organic conceptualisations and connectionism. Applying organic concepts to systems gives systems metabolism in that they are both self-producing and self-maintaining (autopoietic). Further, the systems are quite open and hence, responsive to changes in the environment to which they adapt and innovate by developing new behaviour. Control in such systems is distributed and the systems are self-organising. The connections between the agents of the system facilitate communication which, in conjunction with the numerous feedback loops, causes attractors to occur.

The independence / autonomy of the agents within the system means that the system has an anarchic power symmetry at its outset. As the system develops, the parts evolve with each other to fit the broader system and its environment (coevolution); its self organising properties can develop a control structure / leadership with an asymmetrical distribution of power. Such self-organising also concerns dynamical attractors being present in the system which yield areas of stable operation. Because a complex system contains many dynamical attractors, the system has a variety of possible behaviour; as under chaos theory, the actual behaviour of the system depends on its initial conditions and configuration as well as subsequent perturbations – thus, the history of the system determines its behaviour and the development of the system is not a reversible process.

Bertelsen (2003) and Bertelsen and Emmitt (2005) examine Lucas's axioms of complexity in relation to construction and construction clients. Their categorisation is extended in table 1.

Kaufmann (1993) classifies systems as ordered, complex, and chaotic. Complex systems are, commonly, regarded as being 'at the edge of chaos' as they exhibit some order through interactions of their internal components, notably the feedback loops which generate dynamical attractors.

Table 1: Classification of Axioms of Complex Systems (Sources Lucas, 2005; Bertelsen, 2003; Bertelsen and Emmitt, 2005)

AUTONOMOUS AGENTS	***UNDEFINED VALUES***	***NON LINEARITY***	***NON EQUILIBRIUM***
Autonomous agents: *Systems comprise independent agents; initially anarchic power symmetry; structure /leadership emerges through self organisation*	***Fitness:*** *The distribution of optima can be modelled by the concept of fitness landscapes*	***Attractors:*** *Systems contain multiple dynamical attractors; similar systems may behave differently, depending on their histories*	***Fuzzy functions:*** *Systems' functions co-evolve through combinations of emergent values*
Co-evolution: *The parts evolve in conjunction with each other to fit the system's environment; such fitting is dynamic*	***Non-uniform:*** *Parts – agents and relationships – evolve separately according to different rules*	***Emergence:*** *Systems' properties are higher level functions of the systems, notably synergistic*	***Instability:*** *In the long period, step changes or catastrophes occur with sudden swaps between attractors*
Downward causation: *The parts create the whole system but also the parts are affected by the emergent properties of the whole*	***Undefined values:*** *The meaning of systems' interfaces with their environments evolve*	***Nonlinear:*** *Outputs are not proportional to inputs; the whole is different from the sum of the parts; holism applies*	***Mutability:*** *Random internal changes occur yielding new internal configurations*
Non-standard: *Systems contain structures in space and time which are heterogeneous and changing*		***Phase changes:*** *Feedback leads to sudden jumps in systems' properties*	***Non equilibrium:*** *Systems operate far from equilibrium; they are dissipative; energy flows establish semi-stable modes as dynamical attractors*
Self-modification: *Parts can change their associations/connectivity freely – randomly or by evolved learning*		***Unpredictability:*** *Systems are chaotically sensitive to initial conditions*	
Self-reproduction: *Systems can replicate themselves; new structures can occur in the copies*			

Whilst organisations, their members (and stakeholders) and groupings (markets and industries) seem to desire order to facilitate prediction and control to foster own performance towards pre-determined objectives, changes in the environment and perturbations within the system, at various levels – inventions and innovations, etc. – provide frequent disturbance of any (static) equilibria. Thus, a variety of equilibrium perspectives have developed – notably, the profit maximising equilibria of the firm and of the industry according to neo-classical economics, and the alternative analyses for firms according to Cournot, Bertrand, and Nash equilibria.

The notion of dynamic equilibrium, a system being in dynamic equilibrium when inputs equal outputs, has proved interesting but has been overtaken somewhat by chaos theory and its development into complexity theory. In complexity theory analyses, although parts of a system my appear to be close to, or in, equilibrium (attractors) that situation does not prevail and so, when considering the whole system, it is far from equilibrium, although it may exhibit order on occasions.

Thiétart and Forgues (1995) examine three types of equilibrium which, largely, are determined by the natures of feedbacks within the system. Negative feedbacks, via their effect of dampening the influences of variables, act to return a system to its prior/initial state – stable equilibrium. Positive feedbacks reinforce changes made by variables and so, small changes increase geometrically – explosive equilibrium (leading to collapse of the system). When both positive and negative feedbacks are present in a system simultaneously, the system may reach a stable equilibrium (point attractor), may return to a previous state periodically – reach periodic stability (periodic attractor), or its behaviour can be more complex, including being completely erratic, or ‘chaotic’ – the system’s behaviour is contained within a strangely-shaped surface (strange attractor). In the final condition, the system is sensitive to initial conditions. The state of a system is dependent upon the natures and strengths of the relationships between its agents.

The recognition of the essential impact of the relationships between the agents in a system contrasts with more traditional paradigms of systems in which the agents are the focus in designing systems as deterministic, predictable chains of summable parts to achieve a specified ‘primary task’. In such systems, feedback is regarded as, essentially, a monitoring/reporting mechanism to inform management so that control (and performance improvement) can be exerted; feedforward, analogously, operates for predictive control.

The autonomous nature of the agents in the system and the constantly evolving relationships between them, as well as the other axioms of complex systems (see table 1), determine that not only are the outputs from the system unpredictable but also control cannot be exerted/imposed from outside. Such a situation is in stark contrast with much traditional organisational theory and analysis which employs external and internal controls to enhance performance towards that predicted, in pursuit of a pre-determined primary task. Complex systems do have order rather than being totally chaotic, there is structure but it is self-determined and coevolving, there is control but within the system rather than imposed on it, the system does respond selectively to environmental forces but the outputs remain unpredictable.

3. Construction project realisation

Construction projects are realised through the combination of a great diversity of activities constituting design, construction, and regulation/control functions (see figure 1). Either end of the realisation processes, client/customer – demand side – activities variously occur as the rationale for commissioning the project and for its occupation, use, adaptation(s) and final disposal, increasingly with (partial) re-cycling into subsequent projects.

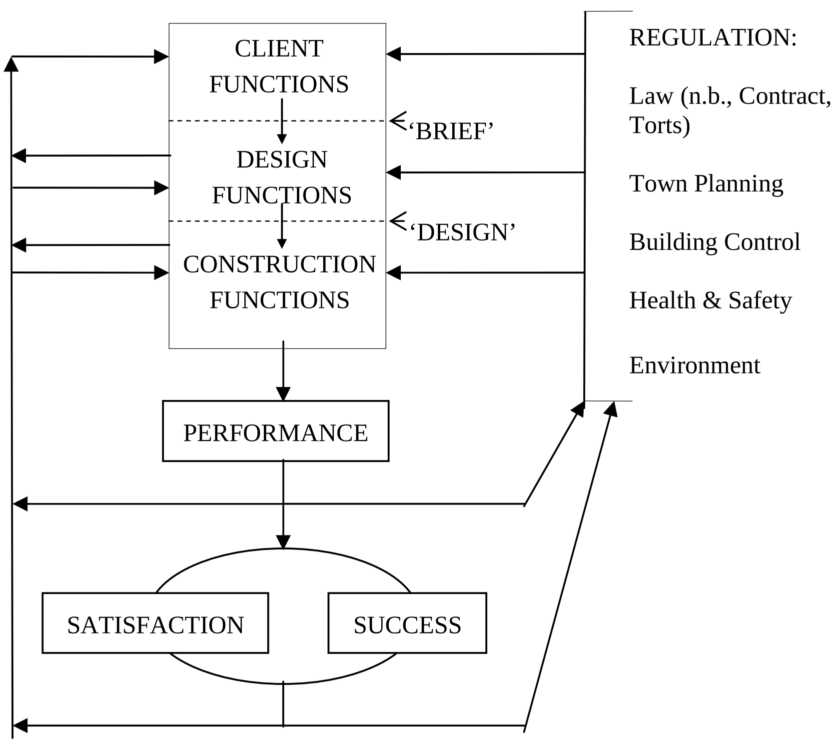

Figure 1: The Project Realisation Process (developed from Fellows, 2009).

<u>Notes</u>:

(1) Performance leads to satisfaction of participants and, hence, (perspectives of) project success.

(2) Performance-Satisfaction-Success also produces feedforward in the ‘cycling’ of project data and information to aid realisations of future projects through participants’ perception-memory-recall filtering (‘experiences’).

(3) A similar model applies to projects in use (beneficial occupation) but with ‘Facilities Management’ and ‘Maintenance and Adaptation’ replacing ‘Design’ and ‘Construction’ as major functionary groups.

Robertson (2004) notes that if agents and relationships, the totality as depicted in figure 1, are considered as a system, it is possible that the system is complex. That observation is reinforced by Feigenbaum (1978, 1979) who asserts that chaotic behaviour is probable when the number of agents exceeds two.

Over many years, construction project realisations have been widely criticised for poor performance, criticism which has been levelled at the performance of the products also. The bases of such generic criticisms, which, commonly, concern fragmentation, are founded in traditional organisational management theories and assumptions, epitomised in rational behaviour and the quasi-mechanistic paradigm. That paradigm sees organisations through a reductionist lens with organisations being quite stable systems with pre-determined, rigid (formal) structures such that input requirements, transformation processes and resultant outputs are deterministically predictable with ease and accuracy, irrespective of the procurement approach adopted. Changes can be problematic but are addressed by adaptation of mixes of resources, most of which are available quite readily (especially, given adequate funds).

Weick (1977), Quinn and Cameron (1988), and many other researchers have questioned the 'traditional' perspective of organisations, suggesting, instead, that "…political games between organizational actors, intuition, and random events come into play in shaping an organization's future" (Thiétart and Forgues. 1995). Further, the structure of the construction industry has undergone significant changes in many countries since 1980 such that 'main contractors' no longer execute any construction operations themselves (using directly-employed operatives) but, exclusively, manage subcontractors. Further structural changes have been occasioned through the widespread use of concession arrangements for procurement by public sector clients – notably, the various forms of public private partnerships (PPP) – which have brought about new financially-driven organisational structures, including (more) temporary consortia (Gruneberg and Hughes, 2006).

4. Organisational culture in construction

Organisational culture, which develops from the organisation's founders and others who are influential in its history, is how we do things in this organisation (Schneider, 2000), or, "…the collective programming of the mind which distinguishes the members of one organization from another" (Hofstede, 1994). Schein (1984) determines two primary types of organisational culture: 'structured' – a bounded, rigid organisation with clear rules and requirements; 'free flowing' – an unbounded, egalitarian organisation without much formal structure, thereby encouraging debate and internal competition (analogous to the mechanistic-organic typology of Burns and Stalker, 1961).

Even if not employing 'competing values' (e.g, Cameron and Quinn, 1999) directly, use of dimensions to assess cultures operates similarly (e.g., Hofstede, 1994: Process – Results Orientation, Job – Employee Orientation, Professional – Parochial, Open – Closed System, Tight – Loose Control, Pragmatic – Normative). The characteristics of organisational cultures, which are constructed by combinations of the measurements along the various dimensions, may be represented as power, role, task or person (Handy, 1985); an alternative is market, hierarchy, clan, adhocracy (Cameron and Quinn, 1999).

The Tavistock Institute of Human Relations (1966) noted the importance of informal, social systems for performance on construction projects. "…informal structures emerge and persist in a way that is remarkably robust to changes in the formal organizational structure" (Anderson, 1999). Management, whether addressing formal or informal structures (systems), according to more 'traditional' perspectives, is the active factor (agent) to determine and achieve performance through securing and organising the other resources (agents) in the system. That perspective leads to a definition of management – making and implementing decisions concerning people to perform tasks in pursuit of objectives. However, Simon (1964) considers that it is questionable if decision making in organisations is goal-directed but suggests that it is directed at determining new courses of action which satisfy the perceived set of constraints and so, accepting bounded rationality, may be more akin to the 'garbage can' model.

Meyer and Rowan (1977) note that organisations must optimise several performance criteria, both output and maintenance (Scott, 1992) to survive and to grow. Those criteria are increasing in number and diversity and so, organisations, and their managers, must juggle a diversity of expectations and constraints that lead to a complex payoff function beyond optimisation (March and Simon, 1958). Thus, commonly, organisations pursue new goals in reaction to environmental forces, as characterised by Tavistock (1966) in respect of construction projects as temporary, multi-goal coalitions.

Given the widespread criticisms of construction – projects, organisations and the industry – portraying a dangerous, dirty, macho, opportunistic, etc. culture in which performance is unreliable, risks are high and returns inadequate, it remains widely beloved by its members – a way of life, with a jovial, innovative, and 'can do' side to the culture (witness 'Bob the builder'!). The industry contains, and, further, is very closely associated with a vast diversity of organisations; likewise the organisations' activities and the projects which are executed. Hence, even for a single country, the construction industry is a cultural conglomerate, more extensively so through mobility of labour and multiplied on major, international ventures.

Examining organisational culture profiles in construction yields notable spread on whichever dimensions are employed for both individual dimensions and their aggregation. Those cultural profiles are both impacted by the national culture(s) and impact on the organisational climate. A further set of interactions occurs through globalisation. What is important is that culture arises informally and dynamically through humans and their relationships and, although aspects may be embodied in formal structures, only the formalities which appropriately represent the members and relationships between them are sustainable.

5. Discussion: construction cultures in complex (system) organisations

Boisot and Child (1999) depict the (informal) organisational transaction-governance structures of bureaucracies, clans, fiefs and markets in 3-dimensional I-Space. The dimensions of codification, and abstraction of information yield C-Space (culture space, Boisot and Child, 1996) and are supplemented with diffusion to yield I-Space; codification and abstraction measure cognitive complexity while diffusion measures relational complexity. Thus, bureaucracies exhibit low transactional complexity, fiefs and markets are medium, and clans are high; those positionings relate to their relative locations along the spectrum from ordered to chaotic regimes. Examination of the adhocracy form of organisation (culture) results in its being high complexity, particularly due to its emphasis on invention/innovation hence, quite high in both cognitive complexity and relational complexity, placing it potentially the closest to the chaotic regime, as noted in table 2.

Table 2: Locations of Organisations, by culture typologies, in I-Space (developed from Boisot and Child, 1999; Cameron and Quinn, 1999)

<table>
<tr><th></th><th>Undiffused Information</th><th>Diffused Information</th></tr>
<tr><td>Codified Information</td><td>Bureaucracies
Information diffusion limited, under central control
Relationships impersonal and hierarchical
Submission to superordinate goals
Coordination hierarchical
No need to share values and beliefs</td><td>Markets
Information diffused extensively but no control
Relationships impersonal and competitive
No superordinate goals, individuality
Horizontal coordination by self-regulation
No need to share values and beliefs</td></tr>
<tr><td></td><td colspan="2">Adhocracies
Information diffusion limited by diversity, little control
Relationships personal and competitive
Submission to superordinate goals
Coordination horizontal through self-regulation
No need to share values and beliefs</td></tr>
<tr><td>Uncodified Information</td><td>Feifs (Hierarchies)
Information diffusion limited by lack of codification to face-to-face relationships
Relationships personal and hierarchical
Submission to superordinate goals
Hierarchical coordination
Need to share values and beliefs</td><td>Clans
Information is diffused but limited by lack of codification to face-to-face relationships
Relationships personal and non-hierarchical
Goals are shared through negotiation
Horizontal coordination through negotiation
Need to share values and beliefs</td></tr>
</table>

Unlike most production industries, but in common with other project industries, construction, via unique assemblies of components, in individual locations, at different times, usually produces bespoke products for which performance targets are contracted in advance. However, unlike most other project industries, the norm in construction is not only the separation of design and production but, further, the vast fragmentation (individuality of activities and organisations) within design, production and assembling in the project realisation process. Thus, the agents in a construction system are only partially connected – as expressed in standard contract terms and in industry procedures – which generates areas of order (Anderson, 1999) and, given the temporal changes in construction realisations, the systems evolve dynamically. Further, both inter- and intra-projects, the agents and relationships between them are in flux which generate both instability and additional complexity.

Notoriously, agents within a construction system tend to adapt opportunistically to changes which they perceive (and/or predict) in endeavouring to improve their own rewards. Their actions seem to accord with a temporal, episodic model – the present's actions both depend on past actions (and their consequences) and impact on actions in the future – and to accord to a power law (as in economic time series, etc.); therefore, construction systems and their agents comply with those aspects of complex behaviour. The systems' operating landscapes also change continuously because rewards to an agent are believed to depend on the actions of other agents and so, adaptations produce coevolving, local, temporary order/equilibria (denoting the presence of attractors). Holland and Miller (1991) note that such systems operate at considerable distances from their optimal performance equilibria.

For strategy, Thiétart and Forgues (1995) observe that "…systematic, coordinated, planned and thought-out approaches are combined with muddling through, hesitation and impulsive responses….Reality contains elements of rationality, formality and order mixed with intuition, informality and disorder." Further, "Experimentation, innovation and individual initiative…are sources of instability" hence, those attributes, which are highly valued in project managers, also contribute to chaotic or complex system behaviour. So, acknowledging that such organisations' futures cannot be predicted (except possibly partially in the short term only), managers tend to progress incrementally and regard alternative futures as gambles rather than relying on forecasts which they consider (if only through experience) to be highly fallible.

Unfortunately, the usual processes for securing work in the industry, commonly fuelled by vested interests and simplistic techniques in widespread usage, serve to inculcate false certainty over prediction and control of the future. Thus, with performance realisations being significantly different from those predictions, dissonance and, consequent, dissatisfaction, lead to recriminations, conflicts and compensation claims. Particularly due to increased power of those who exercise demand and their (understandable) desire for certainty, coupled with intense competition in supply, construction suffers by acceding to such desires, rather than following the reality of the supply situation and, at least, adopting stochastic approaches to performance forecasting.

6. Conclusions

Construction projects are complicated, comprising many different resource inputs, from independent participants, subject to increasing regulations, in varying locations, at particular times, impacted by changing environments, using alternative processes, and all in bespoke combinations. Thus, it is common for the industry to be viewed as unique and for realised performance to be considerably different from desires and forecasts. Reugg and Marshall (1990) articulate a major contributor to such generic problems – that construction activities are stochastic processes but common forecasting techniques are deterministic and operate as 'best-guess', conglomerate estimates of input variables but treated as certain estimates with results presented in single-figure, deterministic terms.

Examining the features of construction projects, organisations and the industry in the context of complexity theory, it is evident that the axioms of complexity are applicable in construction. Thus, evolutions in construction, its autonomous agents and relationships between them, and the (essential) responsiveness to the environment, indicate the operation to be in a complex regime. Hence, stability (equilibrium) is only local/temporary, control occurs through self-development, and forecasting (of performance) is more hazardous than, even, common stochastic methods accommodate.

Although this study is an initial exploration of theory and literature, it is clear that the emerging paradigm of complexity offers much potential for gaining understanding of construction. That requires the establishment and execution of a thorough agenda of research in the complexity paradigm which casts aside the staid perspectives on construction to undertake open and rigorous investigation – a cultural development and paradigm shift is highly desirable.

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