ON THE DOING OF BUILDING WORK: ‘WAYS OF KNOWING’ AS MODES OF COPING WITH COMPLEXITY

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Research employing a practice lens has demonstrated that emergent, informal and tacit ways of knowing are influential in the production of the built environment. In some respects, practice theory helps reveal something of the underlying complexity of building work. Indeed, large, real world systems are unavoidably complex and this complexity can only be restructured; it cannot done away with. Workers have to cope by way of both established routines and emergent practices. However, the relationship between practice and complexity is seldom studied within the construction management literature, and so that “ways of knowing” might represent approaches to coping with complexity has so far not been made explicit. In this paper we argue that combining systems and practice theoretical concepts might provide new insights into the intricacies of construction production. We draw upon ethnographic vignettes to illustrate how it is possible to analyse how complexity is processed in practice and how unpredictability and uncertainty in several disparate systems are routinely dealt with through building work. This ‘knowing-in-practice’ manifests as a mode of coping with complexity and as emergent outcomes of creative efforts drawing on a combination of established routines and informal practices. Further explicating how this happens represents a significant research agenda, one which could begin to close the gap between the dominant focus on codifying construction management practices on the one side, and bettering our understanding the actualities of building work on the other.

Keywords: complexity, emergence, ethnography, practice theory, systems theory.

INTRODUCTION

Despite arguably being one of the most prevalent topics within the project management literature in recent years, the focus of analysis around complexity is mainly on how to organise for complexity, rather than on the ways in which complexity is dealt with in the process of doing building work. Reflecting Cooke-Davies et al (2007) in relation to the complex responsive processes of relating, this refocuses attention from management ‘of’ project complexity to managing ‘in’ complexity. However, the mobilisation of concepts taken from complexity theory remains limited. Brady and Davies (2014, p. 22) cite Geraldi, Maylor and Williams’ (2011) claim that ‘complexity remains ambiguous and ill-defined in much of the project management literature’. They review some of the important contributions to this literature and propose a simple synthesis in the form of a distinction between structural and dynamic complexity. These are defined respectively as ‘arrangement of components and subsystems into an overall system architecture’, and as

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'changing relationships among components within a system and between the system and its environment over time' (Brady and Davies, 2014, p. 24). Managing both of these aspects is essential for project performance, but in doing so a balance has to be struck between hierarchical structuring and control (to curtail structural complexity), and the need for involvement, interaction and innovativeness (in finding ad-hoc solutions to emergent problems). It would seem, therefore, that the complexities of project work will always require a blend of control and emergent practice, and that formality/informality will inevitably be mutually constituted in, and through, action.

As has been argued cogently by Kreiner and Damkjær (2011), appearances are often deceiving in construction, and it is very easy to draw hasty conclusions (or learn the wrong things), from successes as well as from failures in construction work. This is because, in the practice of building many things are related, and in ways that are often surprisingly hard to grasp and even more difficult to predict. One reason for this is that actions that at first sight are considered relevant with respect to only one system often are revealed as having effects in several systems at the same time. Specific examples of this will be given as illustrations in two vignettes below, to make it easier to appreciate that many of the intricacies encountered in the production of the built environment arise "behind the scenes" or in what can be seen as layers of project realities located below the observable surface of operations. The "art of building practice" encompass making sense of these embodied and tacit aspects of construction. Coping with complexity by managing it (curtailing it, structuring it) and at the same time navigating in it represents a core challenge for the construction practice. Exploring this aspect of construction and building in turn represents an important challenge for construction research, and in this context Pink *et al.*'s (2010) argument that theories of practice, knowing and aesthetics promises more theoretically sophisticated ways of understanding building work is particularly significant.

The question addressed in this paper is whether it makes sense to develop a theoretical perspective on construction that combines insights from systems theory and practice theory when the goal is to understand in new and incisive ways what goes on in the production of the built environment. This is not to say that such perspectives are commensurable, but we do posit that their co-mobilisation might provide new ways of thinking about the doing of building work. Thus, whilst the positioning of this research observes calls for a renewed focus on the importance of informal and emergent practices in construction practice (i.e. Chan and Räisänen, 2009), our focus is on complexity as a systemic phenomenon. Couched in this way, 'knowing' in construction work can be conceived of as emergent, creative accomplishments in which complexity is navigated, but also as modes of managing - or curtailing - complexity, by way both of established routines and informal practices. "Ways of knowing" are then the established conceptions and procedures (routines) representing the practice of diverse contributors and stakeholders in construction, and the argument made here is that these various approaches embedded in practice represent different modes of coping with complexity. Further explicating how this happens, and how different approaches add to or interfere with each other, provides a significant research agenda for those seeking to begin to close the gaps between construction procedures and the (often conflicting) actualities of construction practice.

THEORIZING THE LINK BETWEEN EMERGENCE AND COMPLEXITY OF BUILDING

Complexity, which is a trait of systems, has emerged silently to become an essential feature of modern society and a major challenge in the public sector as much as in private enterprise (Rycroft and Kash, 1999). The basic reason is that the world due to constructive efforts of human beings is becoming increasingly systemic. Complex systems are 'made up of a large number of parts that interact in a non-simple way', according to Simon (1962). Luhmann, drawing on systems theoretical concepts from Simon and others, explains complexity in his own meticulous way (Luhmann, 1984, 1995). Systems, he says, are sets of connected elements in space and time. Since elements have limited ability to relate to other elements, and since the number of possible linkages in a system increases geometrically - that is, much more than the number of elements - elements cannot all be *directly linked* in large systems. It is this lack of integration, Luhmann says, that makes systems into complex systems; that makes the interaction of parts *non-simple;* and that makes uncertainty into an inexorable part of complex systems' behaviour.

In the domain of construction research, Baccarini (1996) in his survey of contributions that analyse complexity in construction concludes that complexity in construction relates to (1) the differentiation and number of elements (e.g. tasks, specialists, components) and (2) connectivity and the degree of interrelatedness and interdependence between these elements. He argues that construction complexity takes many forms, and that it is important to be specific about the type of complexity that is being considered. Whether this complexity is a product of the increasing interrelatedness between elements or the incomplete integration and the specific configurations of linkages is debatable, but according to Williams, what is clear is that the heterogeneity of technical systems and their multiple dependencies contribute greatly to complexity in projects (Williams, 1999). Not all of these depend on each other, but many do, and in ways that are not always explicit and easy to map (Baccarini, 1996; Gidado, 1996).

It has been claimed that construction is among the most complex and fragmented (least integrated) of industries (Fearne and Fowler 2006). A large number of professions and trades representing heterogeneous knowledge bases contribute to construction processes. Williams (1999) argues that technological and organisational complexity is exacerbated by project goals that are ambiguous and changing during the course of projects. Indeed, the social arrangements and processes of relating that are involved in any construction process are important factors that affect project performance (Bresnen *et al.* 2005a, 2005b, 2005c). As Gidado points out, growth of ever-larger production systems with increasingly heterogeneous constituent elements makes construction complex:

> The continuous demands for speed in construction, cost and quality controls, safety in the work place and avoidance of disputes, economic liberalization and globalization, environmental issues and fragmentation of construction have resulted in a spiral and rapid increase in the complexity of construction processes (Gidado, 1996, p. 214).

Similarly, Cicmil and Marshall (2005) draw attention to ambiguity and unpredictability created by multiple and conflicting interests, power asymmetries and unstable and implicit objectives as other factors contributing to pervasive complexity in construction. Based on an ontology of becoming they view projects as processes of complex and unfolding social arrangements.

To sum up, complexity in the form of incomplete, unstable but patterned integration of large and heterogeneous sets of elements is prevalent in construction and has been dealt with in a broad range of contributions to the literature on projects and their management. Complexity makes unpredictability, uncertainty and risk into basic attributes of the realities of construction across the individual, organizational and industry levels. The process view and theoretical perspectives that highlight the importance of emergent phenomena represents a departure from more instrumental and rational theory and provide a useful point of departure for considering how people who work in such a complex arena cope with complexity. At the same time, reasoning regarding complexity challenges based on systems theoretical concepts open up an opportunity for new and more nuanced ways of articulating how practice is geared to overcome the effects of complexity, and how diversity in approaches has effects on production in projects.

COPING WITH SYSTEM COMPLEXITY: A SECONDARY ANALYSIS

To start unpacking how construction practices are geared towards dealing with complexity, an obvious option is to categorize complexity based on the kind of systems which are involved and within which complexity arises. Examples of types of complexity that can be identified in construction in this way include:

- Complexity of mechanical and technical systems making up a built object, including a very large range of basic fabricated elements, such as beams, prefabricated concrete elements, fixtures, tubes, etc., and including advanced technical systems such as elevators, heating systems, electrical distribution systems, etc.
- Complexity of machinery and technology used during the design and building phases, such as the computers and software of BIM systems, lifts, transport equipment, etc.
- Complexity of economic, contractual and administrative systems which are part of a construction project.
- Complexity of social relations between human beings within and between organizations involved in the project.

A somewhat more crude way of distinguishing between different complexities in construction is in relation to two different domains within which they are rooted, namely the technical and social systems. Merely seeing complexity as an attribute of social and technical systems makes it possible to understand better how actors deal with complexity.

In this paper we illustrate this by way of a secondary analysis of high quality published research on the realities of construction work. These interesting contributions formed part the special issue edited by Chan and Räisänen (2009) on informality and emergence. Research carried out on-site by Baarts (2009) and Styhre (2009) both offer ethnographic insights into realities in two complex construction projects. They contain rich field notes that render it possible to reinterpret their data employing a systems perspective. We fully acknowledge that our re-analyses will not capture the detail, insight or nuance of the original authors, nor will our repurposing of their work add value to the original aims of their work. We further acknowledge that we have drawn conclusions here based on an incomplete knowledge of the field site and the data itself. However, we draw upon these excellent studies merely to illustrate the potential intersection of complex thinking with practice-based accounts.

Vignette 1: Coping with complexity in safety work (Baarts 2009)

The paper by Baarts (2009) reports on a fascinating study of safety work, in which she uses ethnographic methods to understand more fully what safety means for the workers, and how safety is dealt with at the building site. The editors characterize her contribution in the following way:

> Baarts' paper describes a fascinating ethnographic exploration of the actual practice of safety on a construction site. Through a selection from her copious field notes, she offers us glimpses of how actors on a construction site navigate between collective and individualistic preferences in dyadic and triadic relationships. Using ethnography, Baarts is able to show how seemingly immutable safety laws and regulations become elastic and adjustable to particular local circumstances, and then, she argues, become established norms that determine the nature and scope of permissible action on site. (Chan and Räisänen, 2009, p. 910.).

We have drawn upon notes on one specific incident recorded by Baarts, in which she and a co-worker, Sebastian, were involved in a near accident as two cranes collided and parts of one of the cranes fell down. The dynamic of the situation is related to the fact that Sebastian is also the workers' safety representative on the site. Baarts' notes are presented on the left side in Table 1, along with our secondary interpretation of their significance regarding our own discussion of systems and complexity.

This incident reveals how workers disregarding rules often do what they do not for stupid reasons, but because situations are multifaceted - in the sense that actions they do in a specific situation actually affects *several systems at the same time*. In this case, we make the point that Sebastian as a co-worker and as a safety representative had to consider his action with respect to three different systems: the technical production system (the crane), the safety system (his role as safety representative) and the social system (his inclusion in the gang of workers).

Baarts argues that Sebastian disregards the safety system because of an inherent technical imperfection in this system, namely the lack of a sufficiently large safety line. An alternative interpretation might be that when attention is directed towards the ongoing complexity processing that this presents challenges in making integrating efforts in several systems at the same time. As a safety representative, Sebastian was responsible for taking action when onsite safety could be improved (the lamp on a jib arm had broken loose), taking care of the production system and re-enacting the safety system by playing his role according to the rules. This might suggest that *not using the safety line* was a deliberate integrative act *with respect to the social system of the gang*. Although it is impossible to know for sure from a secondary analysis, it seems improbable that this tacit knowing in practice would form part of any explicit rule-based system. Rather, it could be motivated by a "way of knowing" that copes with complexity in a tacit way, incorporating concerns that are not immediately obvious to observers, but representing systems integration across both technical and social systems.

Vignette 2: Coping with complexity in rock construction work (Styhre 2009)

As we have argued above, workers actively process complexity by integrative action. That is, they straddle many systems at the same time in the daily activities on a building site, and this complexity processing is an integral part of the 'ways of knowing' that is developed in and through the doing of construction work.

Table 1. The complexity of safety work

Field notes (Baarts, 2009, p. 953)	*Our secondary interpretation*
The two cranes in this particular area of the construction site had collided in mid-air. The jib arm of one crane had broken a lamp on the other's jib arm. (…)	The production system had malfunctioned; two cranes supposed to operate independently had collided. The consequence of the collision was that one subsystem, a crane, had been 'disintegrated' when a lamp broke of and fell down
Since the lamp on the one jib arm had broken loose, it had to be mounted back on the jib arm.	It is the task of workers to reverse the disintegration of the crane as a technical system. An integrative effort has to be made by re-mounting the lamp
As the safety representative, Sebastian was responsible for this task. He stepped into a carrier that had been tied to the crane.	There is a safety system on-site, which is both social and technical. There are materials in specific places, such as safety lines. Furthermore, tasks and roles have been specified and are allocated to people. In this situation, Sebastian is the safety representative, and acts accordingly by re-mounting the lamp on the crane.
He was not wearing a safety line. From the comments of the other workers, I understood that this was a violation of safety regulations. (…)	Sebastian does two things at the same time: he acts as a functional element of the safety system remounting the lamp, however, at the same time he chooses not to act as such an element when he disregards wearing the safety line.
Sebastian was then carried up to the jib arm where he mounted the broken lamp and was safely transported back down to the ground. (…)	The functionality of the technical production system is re-established, and earlier complexity structure is recreated.
Sebastian is a big man, too big to be able to fit into the safety belt required by safety legislation in this situation.	The safety system is in itself complex. There is a lack of integration, according to Baarts due to the fact that people who are too big cannot be accommodated as elements in the functional system.
	A different interpretation from Baarts' is that Sebastian had his own reasons for disregarding the safety rule of using a line. By disregarding this rule, Sebastian reinforces his own integration in the gang as a collective of workers.

The second paper we draw on here illustrates this point. Chan and Räisänen summarise this contribution to their special issue thus:

> Styhre theorizes on the nature of the term [tacit knowledge] as it applies to rock construction and concludes that it is wanting since the assumptions underpinning the literature on tacit knowledge are logocentric, i.e. grounded on the notion that language precedes and is constitutive of knowledge. Styhre argues that skills and operative vocabularies are only partially interdependent. There is another aspect of skills that is separated from language; rather it is dependent on the interplay between material practices and a person's sensory system, e.g. emotions and aesthetic senses (Chan and Räisänen, 2009, pp 910-11).

In this case, we do not have the information to make it possible to consider the social relations between workers. However, we extract a few passages from Styhre's field notes and analysis that in our view, clearly shows how workers operating complex machinery have to deal with multiple technical systems, and how the processing of the complexity of these systems is a largely tacit, informal and emergent phenomenon. The different aspects of operating machinery in rock construction, as described by Styhre, are summarised in Table 2, along with our own systems-informed interpretations of what they mean in terms of coping with complexity. The vignette relates to the operation of machinery used to apply (spray) concrete on the raw walls inside a newly quarried tunnel.

Table 2. The complexity of operating machinery in rock construction work

Field notes (Styhre, 2009, p. 999-1000)	*Our secondary interpretation*
In the case of spray concrete, robots were used to spray the concrete on to the tunnel walls. The robot is here a concept denoting a rather complex set of interrelated technologies (…)	The production system is itself a complex technical system-of-systems
Operating the machine is not that difficult but to do it good is damn hard. Then you need substantial experience (…) To see the whole picture, to see the finished product: Some of them [the workers] are capable of doing a part of the work really well but then they have completely failed to take into account everything else (…)	The production machinery is designed to act upon its environment. A man-machine interface is created for a human being to monitor and guide the systems-environment interplay. The monitoring and guiding presupposes an overall understanding of both the production system itself, the environment, and the way these interact. This understanding is to a large extent tacit
	Those mastering the job are able to understand both the functionality and to sense the limitations of the production machinery
	This can be mastered only with a certain talent, and with a lot of practical experience.
What the skilled co-workers demonstrated was a certain sense of wholeness or unity, that is, the ability to align technology, materials used, the actual conditions in the workspace, and individual performances into a functional process. For instance, spray concreting included the ability to inspect and evaluate the rock surface and conditions of rock (i.e. in terms of the porosity of the rock or the amount of water leakage), the ability to undertake the actual operation of running the spray concrete robot (…) and to carefully pay attention to the equipment *en route*. In addition, all these activities are to be undertaken and executed during reasonably time-compressed conditions.	The most competent workers manage to integrate many different and heterogeneous elements, and a complex pattern of interplay, into a systemic whole. They also are able to grasp this whole as a dynamic, complex system, and to act as guides for the machinery to achieve an uninterrupted process and high quality results.
Quite often you hear sounds (…) you may see the movement of the machine (…) You may see that it is not functioning properly on the concrete: it puffs and hisses and then there is something wrong (…) You can hear on the beat of the pump that it works as intended.	Sensory information is critically important to be able to guide the process, as the overall production system has not been developed to the stage where it is able to monitor and regulate itself. The complexity of this imperfect system is such, that not controlling continuously the interplay of systems and environment, unavoidably will lead to sub-optimal outcomes, most probably systems break-down

The many aspects of the process have to be controlled in a time-critical manner, and the ability of the worker to manipulate parameters based on multiple sense data (sight, sound, smell, sense of rhythm, etc.) is crucial. The analysis in this case therefore highlights only integrative efforts that are within the technical domain. The example serves, however, to support a claim that that workers in their practice actively process complexity by way of integrative action, and that they do so by dealing with complexity in many systems at the same time. Furthermore, their emergent and tacit 'ways of knowing' are instrumental to coping with complexity in the doing of building work.

DISCUSSION AND CONCLUSION

As pointed out in theoretical section above, elements of systems theory and practice theory may together open up new questions around the inherent challenges in the production of the built environment. Indeed, systems integration has been a concern of practice theorists already in the past. Gherardi suggests that practice is 'knowing how to align humans and artefacts within a socio-technical ensemble and therefore knowing how to construct and maintain an action-net, which is interwoven and deployed so that every element has a place and a sense in the interaction' (Gherardi, 2009, p.117, cited in Gluch, 2009, p.961). Although choosing words such as *action-net* and *ensemble*, what Gherardi describes here can easily be conceived of as acts of systems building and integration. Saying that every element should have "a sense of place in the interaction" can be stated in systems language as systems are being built and people have to attend to the complexity as the system that is being built.

To build effectively and efficiently and to create an object of high quality in a process that is safe for workers involved, both system building and complexity structuring has to be considered. Clearly, not everything can be connected directly to everything else, but both direct and indirect dependencies have to be taken into account. This is even more demanding than when, as Gherardi (2009) describes, an action-net has to be 'interwoven and deployed so that every element has a place and a sense in the interaction'. Our re-interpretations of small pieces of the works of Baarts and Styhre suggest the combination of formalised knowledge and emergent tacit knowledge has to be combined in order to cope with complexity. Not everything can be learnt through practice. Over time, knowledge about elements and linkages have to be accumulated and compiled in structured knowledge areas. Professionals and artisans live from the active relating of structured and explicit knowledge, and the tacit - or to use Styhre's term - aesthetical knowledge developed in practice. The substantive challenge is to see coping with complexity and the doing of building work as a product of the *combination of the informal and tacit ways of knowing with the formal and codified*.

Kreiner and Damkjær (2011) have argued that appearances are deceiving in construction. High levels of quality and safety can only be achieved if hasty conclusions based on experience, are avoided. One way to do this in construction research is to engage with theories of practice, knowing and aesthetics, which promise new and more adequate ways of understanding building work (Pink et al 2010). Following Pink *et al.*, we contend that more ethnographic research is needed to unpack the layers of reality that building workers have to take into consideration in their daily activities. At the same time, we believe the deeper understanding of multiple co-existing and interdependent systems add to this, and that the combination of concepts from earlier disparate theoretical areas will offer opportunities to better frame our knowledge of building work as a complexity processing system.

New research that builds on the ideas presented above is underway and will probe more deeply into the realities of building work. This will help untangle how practices and ways of knowing (encompassing established ways of knowing and working, as well as creative solutions to emerging challenges) are often anchored to disparate conceptualizations of what relevant systems are. Framed in this way, complementary and contradictory approaches to complexity processing are inevitable, but merely reflect the multiplicity of approaches to doing of construction work.

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