DEVELOPING COLLABORATIVE CAPACITIES IN INDUSTRIALIZED BUILDING: ROADMAP FOR KNOWLEDGE TRANSFER

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Industrialized building (IB) has been linked to a number of benefits such as improved worker safety, shortened construction times and less material waste. In Australia's housing construction industry, however, uptake of industrialised building has been low and a number of key barriers have been identified. Industrialised building requires a fundamental transformative effort in the housing sector. Local experience and international research suggest that barriers can be addressed by large-scale collaboration, but collaboration has not been systematically explored in the industrialised building domain. Our aim in this study is to examine collaborative practice in five innovative supply chains to enrich theoretical conceptualizations of collaboration through a processual framework that uses the stages of actor-network theory as a scaffold (ANT). Each of our five industrialised building case studies had motivations in varying degrees related to safety, health, well-being, and social and environmental sustainability. Qualitative data was gathered from 29 semi-structured interviews. Based on our analysis, we proposed a framework that examines how collaboration develops and evolves across supply chains. We then took this analysis further into a stage of interpretation. We presented a systematic, narrative-centred process of knowledge translation that transforms research findings into actionable knowledge, thus proposing a method for addressing the persistent evidence-to-practice gap in construction. This knowledge translation process allowed us to identify specific competencies that are critical to building collaborative capacity, thus contributing to practice by developing a roadmap towards a comprehensive behavioural framework for collaboration in industrialized building.

Keywords: actor-network theory, collaboration, competency building, industrialized building, knowledge transfer

INTRODUCTION

Australia has historically has exhibited robust housing indicators (Kitson, Thompson & Chaplin 2015), but recent reports have shown a number of alarming trends. Australian house prices, for example, are now the second least affordable in the world (Demographia 2016) and construction times have increased by 40% over the last two decades (Gharaie, Wakefield & Blismas 2010). Such issues have been linked to the housing sector being highly fragmented and craft-based (Loosemore, Dainty & Lingard 2003). In recent times the promise of an industrialised manufacturing production approach to housing construction known as "industrialized building" (IB) has been suggested to address this myriad of challenges, as international research has linked IB methodologies to benefits in efficiency, cost, innovation, and environmental

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and social responsiveness (Blismas & Wakefield 2009, Pan & Goodier 2012). Still, the number of IB champions in Australia has been limited, and uptake remains low. Local case studies have pointed to numerous hurdles to IB, including inconsistencies in regulations across the country and resistance from unionized labour (Blismas & Wakefield 2009). However, these case studies, while insightful, tend to overlook an important consideration: that many of these barriers are underpinned by the fundamental problem of fragmentation. Housing supply through industrialised building is a complex "problematique", an issue that can only be addressed through the creation of intricate interdependencies among diverse stakeholders. In such complex situations, collaboration has been identified as the only viable response (Gray 1985).

In this paper, we contribute to research that seeks to enrich theoretical understandings of collaboration in industrialized building by presenting the results of our analysis of exemplar case studies where there was adoption of industrialised building. Specifically, our aim is to enrich existing conceptualizations of collaboration by proposing a processual framework to analyse how collaboration emerges and stabilizes in industrialized building networks, building on nine elements of collaboration and using concepts from an analytical approach known as actor-network theory. One important impact of this conceptualization as far as practitioners are concerned is that each element can be explored more deeply through the development of narratives. We argue that narratives provide a robust, richly-textured foundation that can be translated into knowledge forms readily applicable for practice. We explicate the steps of this knowledge translation process and in doing so we propose one approach for bridging the persistent gap between evidence and practice (Chapman 2013). This knowledge translation process allows us in this case to identify skills that are required to develop collaborative capacity in industrialized building.

COLLABORATION IN INDUSTRIALIZED BUILDING

There are numerous challenges to conducting theoretical research in collaboration in industrialized building and, more broadly, in construction settings. Two are mentioned here. First, there is currently very limited systematic work that seeks to develop a theoretical definition of collaboration in these areas. A number of studies have identified collaboration as a facilitator of IB processes (Tezel & Nielsen 2013), as a condition that could aid behavioural change within a sector seen to be problem-ridden (Sunding & Ekholm 2015), and as a driver of industrial renewal (Håkansson & Ingemansson 2013). These studies acknowledged the importance of collaboration as a driver for change. Nevertheless, there is limited work that seeks to address the more fundamental question of what collaboration actually means in IB settings. A literature review on collaboration in the broader field of construction supply chain management shows there is an emerging body of work that has begun to address this (see for example Walker &Walker 2015), but overall theoretical development has remained limited. A second challenge to conducting theoretical work on collaboration is the lack of clear processes for translating research findings into a form of knowledge that is useful in real-world settings, for example policy-making or actual business practice. At present there is limited research that explores how to translate research to practice in construction (Chapman 2013).

These gaps are persistent in construction research in part because there are nuances to construction settings that make it challenging to examine collaboration phenomena closely. Construction contexts are deeply conflict-ridden, permeated by human as well

as non-human actors, and comprised of supply chains, some temporary, others more persistent (Pablo & London 2016a). These could very well lead to forms of collaboration that differ in subtle ways from those that emerge in more homogenous settings. We argue here that while these unique features of construction can make collaboration be difficult to capture, there are certain research approaches with methodological toolkits that lend themselves to discerning these features in fine-grained ways. One such approach is actor-network theory.

ACTOR-NETWORK THEORY

Actor-network theory (ANT) is an analytical approach built on the premise that much of what we see in the world is the outcome of human and non-human actors interacting in heterogeneous networks (Callon 1999, Law 1992). Networks are created mainly (not entirely) by a key actor called a prime mover, who lays the groundwork for a network by defining a problem and formulating a solution (*problematization*). The prime mover then seeks humans and non-humans that can address the problem and implement the solution. An important task here is defining roles for possible actors then implementing strategies to convince potential actors to take on these roles, which may at times be narrowed and simplified to facilitate actors fitting together in a coherent manner (*interdefinition of actors*). The prime mover may succeed (*enrolment*) if actors are convinced to break away from other competing roles and identities *("interessement")*, but it is also possible that they resist (Callon 1999). When actors are enrolled, the network can become increasingly converged to the point that what was once a multi-actor entity begins to look like a single actor (*convergence*). A network that runs according to the same programs and goals over time is described as stable, and through the use of devices (*immutable mobiles*) can expand their programs across time and space. This state of stability may persist but can be interrogated at any time (Law 1992). This process of enrolment, convergence, stabilization and expansion is called translation (Callon 1999).

ANT is a robust analytical device with a methodological toolkit that can capture dimensions of collaboration in construction that could otherwise be overlooked by other approaches. Its assumption of actors being human and non-human carves out space for exploring the role of objects like equipment, buildings, and building products in construction collaboration. Its premise of networks as units of analysis supports the examination of supply chains, in contrast to more limiting approaches that examine collaboration as a phenomenon between autonomous firms. Finally, its notion of networks developing through stages allows researchers to consider that collaboration is a processual phenomenon that evolves as a network of actors evolves (Pablo & London 2016a).

METHODOLOGY

To address the aim of this paper, we used qualitative case study techniques to examine five networks of actors that had successfully completed innovative industrialized housing construction projects supported by large-scale collaboration. These five case networks were selected for the purpose of achieving maximum variation (Flyvbjerg 2006). For example, our mix of cases showed the focal organizations of each network as being at different life stages (two start-ups, two in growth stage, one mature), producing different housing types (detached, low-rise, and medium rise), and mobilizing IB at different levels (manufacturing components, systems, and modular housing). Data was gathered through semi-structured interviews. Questions were framed around four main topics: drivers and barriers to industrialized building, and

drivers and barriers to collaboration. The 29 interviews lasted an average of one hour each, were fully transcribed, and were then analysed thematically. The first round of analysis yielded 100 initial codes, with 60 of these codes being linked to collaboration. These 60 collaboration-related codes were clustered into key categories, which we then initially identified as nine key elements of collaboration[3]:

Element	Definition
Champion	"Convener" provides vision, drives chain through key organizational citizenship behaviours, and ensures roles and tasks of actors fit together
Shared goals	Commitment to a clear set of commercial as well as non-commercial goals (worker safety, environmental sustainability, etc.) is widespread
Comprehensive pool of knowledge, skills, attitudes	Expectations on the knowledge, skills and attitudes of the team as a whole are explicated and upheld, and the right combination is achieved
Openness to change and to IB	Actors are open to change, and are willing to shed traditional mindsets to take on new roles and skills associated with IB
Mutual problem solving	Parties interact directly to solve problems in ways that generate mutually acceptable solutions
Investment in relationship	Relationships are prioritized and maintained over the long term
Shared physical/ virtual space	Co-location and frequent face-to-face meetings are prioritized, and at times supported by IT
Organizing mechanisms	Decisions on team size, member roles, boundary spanners are formalized, or at least made explicit
Explicit, coherent process and output standards	Procedures related to project tasks and output specifications are documented and parties commit to adhering to these procedures

Table 1: List of elements of collaboration and their definitions

We now develop, in two stages, a deeper analysis and an interpretation, the latter specifically aimed towards material relevant for practitioners. In the Findings section, present our enriched analysis, demonstrating how we can move from a static list of elements to a processual framework, that is, one that proposes relationships between elements based primarily on sequentiality. This addresses the paper's aim of enriching theoretical conceptualizations of collaboration, which among other things tend to be predominantly static (Gray 1985). In the Discussion section, we move to the process of interpretation. We use narratives to develop the definition of each key element more richly. The narratives then provide a platform for identifying critical skills foundational to building collaborative capacity in the housing construction sector, an important impact for industry.

FINDINGS

We now propose a framework for defining meaningful inter-relationships between the nine elements. In this case, we suggest these elements are linked processually, in that each element can be primarily (not exclusively) situated in a particular stage of network development as defined by ANT (Figure 1, next page). There are four important points to note about Figure 1. First, it suggests that the nine collaborative elements we have identified (Table 1) are linked to the four stages of actor-network

[3] In earlier work (Pablo & London 2016 b), we identified eight elements and proposed definitions; with further analysis we have refined these slightly and there are now nine.

theory (problematization, convergence, stabilization, expansion). Specifically, four elements are conditions that lead to collaboration in the problematization stage, three are linked to the convergence stage and two are linked to the stabilization stage. Expansion is shown in the diagram but we clarify that it is a new cycle of problematization, convergence, and stabilization related to a new network. We discuss these stages and conditions in detail shortly. A second point about Figure 1 is that it suggests the focus of collaborative activity shifts, starting from a focus on individual actors, then moving to relationships between actors, and finally to mechanisms of work that render collaborative activity durable. This suggests that collaboration is dynamic (Gray 1985); that is, the nature of collaboration changes depending on a network's stage. Third, the two arrows in the centre of the figure suggest that progression through the stages ideally proceeds in a clockwise manner. However, networks in later stages can fall back into early stages (for example when a stable network is disrupted and has to be recreated anew). This suggests that collaboration can also evolve in a non-linear manner. Fourth, the conditions for collaboration laid at early stages must persist in later stages for collaboration to be enduring. Elements 1-4 emerge in the first stage, but they must persist all the way to the last stage for collaboration to be robust. In this sense, collaborative conditions are multi-layered. An exception may be in cases where a new network spins off through expansion and becomes independent of dynamics in the original network. This remains an empirical matter to be explored.

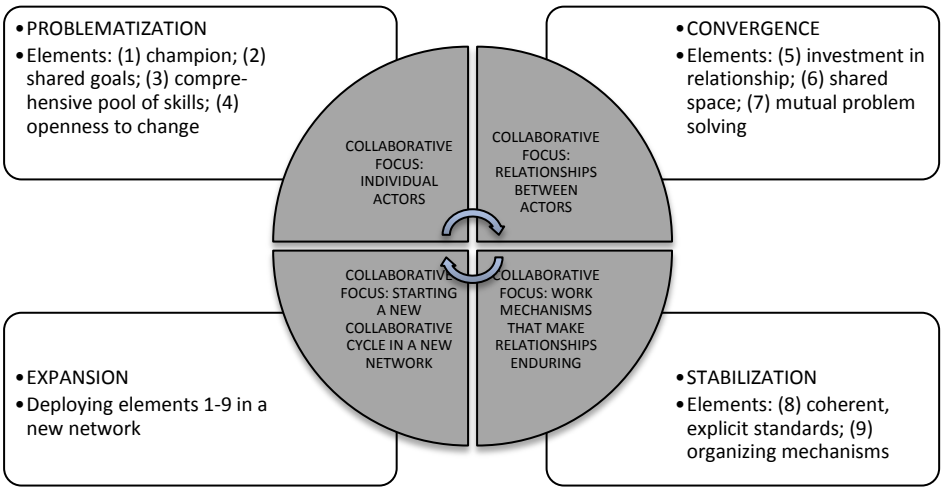

Figure 1: Process-based framework for collaboration driven by ANT

Collaboration in the problematization stage. Figure 1 shows that collaboration in industrialized building begins at the problematization stage, and rests on the fulfilment of four conditions. First, it collaboration begins with one or more champion(s) with enough credibility to challenge the status quo in the housing construction industry. A recurring theme across our case studies was the presence of one or two individuals who made a strong case for shifting, either radically or incrementally, from traditional to industrialized building. In our findings, the champion(s) "problematized" or framed IB goals in ways that transcended commercial motives. We have seen how champions, or prime movers in ANT, have successfully laid the groundwork for collaboration in IB by pointing out how IB addressed commercial goals as well as non-commercial goals like worker safety, design complexity, and environmental

sustainability. Champions were thus highly skilled at formulating a compelling vision or goal for industrialized building (Element 2).

Champions also strategized on the different roles and functions needed to fulfil this vision, articulating the collective pool of skills and expertise (Element 3) needed to achieve the vision. This is a process consistent with ANT's interdefinition of actors (Callon 1999). One champion recounted,

> So we went out to the largest frame and truss manufacturers who had the best detailers in their…pool of employees. We went to a flooring company who [sic] had the ability and cashed up to be able to do all the independent testings that we wanted to be done. And we had the best engineers on board.

This process of enrolment was not always straightforward and unproblematic, as some target actors refused to detach from the mindsets of traditional construction. Key actors like carpenters exhibited significant levels of resistance when confronted with the need to take on manufacturing-based skill sets. One conclusion then is that collaboration in a new network also requires an attitude of openness to change generally, and to radical initiatives like IB specifically (Element 4). An architect noted that key actors had to be "completely on board with prefab, otherwise we couldn't have done it." This openness to change facilitates the translation activity *interessement*, as openness to change makes it easier to cut away actors from the entrenched mindsets, tasks and roles of traditional, craft-based construction. Those actors who were not open to change were not enrolled in the network.

Collaboration in the convergence stage. We have noted that once actors have been enrolled into a network, the shape of collaboration tended to shift, moving from focusing on a loose amalgamation of actors to the interactions giving rise to a seemingly seamless entity that appears to function as one. ANT researchers refer to this state as punctualization (Law 1992). At this stage, relationships become focal. Our research suggests that for collaboration to be characterized by such significant levels of convergence, three additional conditions were needed. One is that actors had to clearly signify their commitment to achieve sustained, long-term partnerships (Element 5). Our findings suggest these could be achieved in several ways. For example, actors showed willingness to go "beyond" contractual agreements by making sacrifices when necessary to assist partners in difficulty. Others accepted the inefficiencies and costliness of relationship building by being present at multiple, time-consuming meetings even if they were "a waste of time", just to build trust.

An important supporting mechanism for building these close relationships was shared space (Element 6). While this shared space presumably could have been achieved through virtual, computer-based connections, our findings repeatedly show that IB actors preferred traditional arrangements involving physical co-location. One team member we interviewed recalled that when they first used IB methodologies, they had an intense six-month period where actors met every week in a single room where critical decisions were made on the spot:

> We wanted questions, answers right there and then… By us having everyone there at the table once we hit an issue we can ask that discipline, how do we get around it, what are my options, bang. Decision is made right there and then, you move on.

The quote also highlights that central to interactions in this shared environment was a process of participative problem-solving (Element 7). One team member claimed that

a considerable amount of time in these meetings was spent brainstorming freely but systematically on anticipated problems. In the process, team members began to draw expert knowledge from one another, leading to people becoming increasingly "like-minded". Engineers and non-engineers began to think alike.

Collaboration in the stabilization/ expansion stages. Following convergence, a network reaches a point where it can begin to operate in a steady and predictable manner (stabilization), such that the prime mover can then seek to extend this ordering over time, and over space to more locations (expansion). These two processes are facilitated by inscribing network programs into texts, oral messages, technological artifacts like machines, or social artifacts like institutions. These devices are often referred to as immutable mobiles (Law 1992). In this case, collaborative interactions became persistent and durable because they were inscribed into two main kinds of immutable mobiles. One involved formalized process and output standards (Element 8). Plans, standards, software, contracts and even simple drawings exercised a powerful disciplinary force over disparate actors, in effect "forcing" players to act in a highly coordinated manner because a shared physical artefact with precise specifications had become central to interactions. That is, drawings compelled actors to collaborate, at times confining actors to deviations of not more than five millimetres. A second immutable mobile involved formalized organizational arrangements, for example clear team structures, rules on optimal team size, member roles, and clearly-identified boundary spanners who could straddle interfaces between specialized teams (Element 9). When these arrangements became documented, they in effect sustained and reified previously fleeting and *adhoc* patterns of collaboration.

DISCUSSION

A key question we ask at this point is how to translate the elements, their definitions, and the framework of collaboration into a form of actionable knowledge. Literature suggests the use of narratives as a robust mechanism for bridging this evidence-to-practice gap (Schreyogg & Koch 2006). Narratives have been described as a valuable source of expert knowledge, as devices for understanding of complex situations, and as tools for conveying detailed descriptions in compelling ways. They serve as a potent vehicle for transforming complex, perhaps even uncodified expert knowledge into explicit knowledge forms that can be systematically disseminated. Narratives can "set up a basis for actionable knowing" (Schreyogg and Koch 2006, p. 1). Actionable knowledge can take many forms; Torrell (2006, p. 248), for example, has argued that "a storied report of past events is the frequent first step in training design." We thus propose a six-step methodology centred on the development of narratives for every key element in the definition of collaboration (see Figure 2).

Narrative development involves a process of data interpretation as defined by Wolcott (1994). It is helpful to contrast interpretation to the earlier process of analysis. Steps 1-3, carried out in previous studies (Pablo & London 2016b), involved a methodical, deductive process of moving from data to codes to themes to nine key elements, a process that is disciplined in that it intentionally stays "tightly bound" to the original data (Wolcott 1994, p. 37).

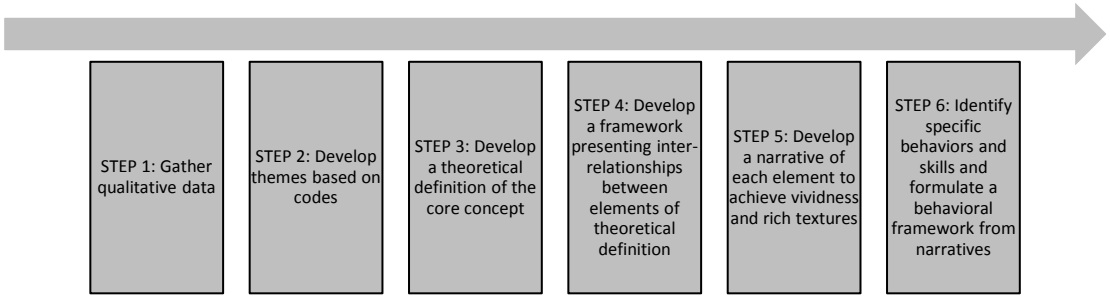

Figure 2: Proposed knowledge translation process based on narratives

Step 4, discussed earlier in this paper, is an extension of this methodical process as well. The outcome of this type of analysis was a complex mosaic of codes and themes. While detailed, this system of codes, rooted in a methodological commitment to stay close to the data, has limitations in terms of interpretative flexibility (Czarniawska 1998, in Schreyogg &Koch 2006).

NARRATIVE: ELEMENT 8	SAMPLE SKILLS FOR PROJECT LEADER
Process and output standards can take diverse forms in IB settings, and can include contracts, work programs, plans, drawings, technical standards, ad formal documentation of processes and procedures. Standards in this case should reflect a number of characteristics: (a) precision, which in IB refers to standards being exact, unambiguous, and accurate, hence their interpretation by different team members is straightforward and unproblematic; (b) efficiently deployed, which in IB settings suggests that they can easily created, recreated, and made readily available in a timely manner for all team members; (c) collectively upheld, which means shared standards are followed by all while specialized ones across disciplines are significantly coherent; and (d) formalized into repeatable systems so that informal, tacit knowledge of value is captured and can be redeployed in other settings.	• Establishes a culture that supports developing and committing to clear and precise process and output standards, particularly those related to manufacture, material flow, transportation and installation • Leads the team in creating transparent process and output standards when there are none • Manages information systems in a reflective manner, balancing timeliness and detail with issues like information overload and too much transparency • Readily identifies points of convergence and divergence between sets of standards (for example can identify if seemingly "new" IB engineering standards are actually equivalent to existing ones) • Identifies best practices currently existing in tacit form, then selects the most effective way to capture in the form of explicit knowledge (written document, software, specialized tool) • Translates best practices and simplifies products into repeatable systems • Commits to agreed-upon team standards, including tight tolerances that characterize IB processes and outputs, particularly those related to manufacture, material flow, transportation and installation • Documents, formalizes, and disseminates standards at optimal levels of detail required by team (balancing tradeoffs between level of detail and simplicity that supports dissemination)

Table 2: Sample translation from narrative to detailed behaviours and skills

As we move to Step 5, however, we now proceed to a process of interpretation through narrative. Interpretation is a different approach to data transformation, as it seeks to present findings in ways that are "unbounded", "inductive" and "generative" (Wolcott 1994, p. 23). The outcome is not a strict and confining system of codes, but a rich story, still linked to data, but with coherence, vividness and texture. Narratives are thus endowed with a level of malleability that lends itself to the process of translation into actionable forms of knowledge. Revisiting the data and bearing in

mind the broad story line encapsulated in the process-based framework, we thus generated narratives for each of the nine elements on collaboration. Due to space constraints we limit ourselves to discussing one example (Element 8). Like any process of interpretation, there is considerable flexibility; other researchers could use our data as a starting point and develop narratives of their own. We present ours as one possibility. Our goal is to point out how the interpretative flexibility of such narratives allowed us to then parse it into specific skills (see Table 2). When this process is carried out for each of the nine elements, the outcome is a robust framework capturing not just skills but also knowledge and attitudes, all observable through through concrete behaviours. The framework can serve as a systematic guide for building collaborative capacity in IB settings in different ways. It can be further translated into checklists that can guide the recruitment and assessment of human resources in IB projects. In our current research, we are using the framework as a basis for developing detailed training scenarios for collaboration, and are exploring the possibility of transforming it into a multi-dimensional collaborative "index".

CONCLUSIONS

Defining and implementing collaboration in IB settings has been problematic, yet it is necessary given that the housing construction sector is fundamentally fragmented. In this study, our aim was to enrich existing understandings of collaboration through a process framework. Building on earlier work that argues collaboration comprises nine elements, we have deepened our analysis by proposing relationships of sequentiality between these elements, using the stages of actor-network theory as an organizing device. This enriched conceptualization highlights how collaboration evolves as a network of actor evolves. It carves out space for exploring how collaborative conditions, practices, and outcomes can be different at various stages of a network's development. We have also proposed a narrative-based approach for translating theoretical concepts on collaboration into actionable forms of knowledge, and presented the beginnings of a behavioural framework for building collaborative capacity in the IB sector.

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