A collaborative practices typology for Australian prefabricated housing networks: convergence, alignment and coordination

Z. Pablo & K. London
University of South Australia, Adelaide, South Australia, Australia

ABSTRACT: Prefabrication in housing construction has had limited uptake in Australia, and preliminary studies have identified a number of possible barriers. However, many of these barriers are underpinned by uninterrogated assumptions, among them limited understandings of the outcomes linked to prefabrication and the type of firm that can lead prefabrication initiatives. Studies also overlook that many of these barriers are rooted in the fundamental challenge of achieving large-scale collaboration. We use actor-network theory and comparative qualitative case study techniques to examine successful cases of large-scale collaboration in housing prefabrication supply chains. We identify eight collaborative practices that drive successful prefabrication, thus contributing theoretically to an enriched multi-dimensional definition of collaboration. We contribute methodologically by using the practices to develop a rubric that guides empirical research in analyzing collaborative arrangements across supply chains. Finally, we contribute to practice by demonstrating that prefabrication driven by different types of firms to achieve diverse outcomes.

1 PREFABRICATION IN AUSTRALIA

Researchers and practitioners have linked prefabricated housing solutions to a number of benefits: economic advantages, improved environmental outcomes, and increased worker safety (Pan & Goodier, 2012). However, housing prefabrication uptake in Australia has been limited, and much of the industry continues to operate largely as a cottage-based and fragmented sector (Loosemore et al., 2003). The reasons for this failure to achieve a large-scale shift to prefabrication are unclear, mainly due to a lack of systematic case studies about the Australian context. Still, a number of explanations for this have been offered, primarily through the identification of a wide range of barriers to prefabrication. Examples of barriers identified are significant startup costs, a market that perceives prefabricated houses as "low-cost" products, resistance from unionized labour and the overall conservative stance of the construction industry in response to radical change (Blismas et al., 2005; Blismas &Wakefield, 2009).

While the initial identification of possible barriers has been insightful, we make two observations. First, a number of them appear to be based on widely-held but possibly unexamined perceptions across key sectors. For example, the seemingly unproblematic association of prefabrication with high startup costs and low-cost prefabricated houses appears to be linked to uninterrogated sets of interlocking assumptions: that prefabrication's main benefits are related to the efficient mass production of houses driven by extensive use of capital; and that this implies standardized houses, large investments in equipment, and the extensive resource base of large, established firms. While these assumptions may have a historical basis, it

has in recent times become less justified and more constraining, in no small part due to technology developments. This has led us to frame our first research question as follows: *(1) What are the different firm typologies and outcomes that are linked to successful prefabrication?* In this paper, we present four case studies that, taken collectively, demonstrate empirically that successful prefabrication can be driven by firms that represent different typologies. Housing prefabrication supply chains can, for example, be led by large and small firms. Prefabrication can be supported by large-scale as well as limited investments in capital. Importantly, prefabrication can support not just outcomes such as standardization, but also outcomes such as design complexity, customization, and exceptional environmental performance.

A second observation is that the manner by which these barriers have been identified (for example in Blismas et al., 2005) leads to framing and subsequently addressing these barriers atomistically as separate issues. We argue for a different approach. We take the view that underpinning many of these seemingly disparate barriers is a more fundamental challenge of achieving large-scale collaboration. We base this on the argument that a number of countries such as Japan, Western Europe, Scandinavia, China and the USA have overcome challenges to prefabrication through a complex process requiring extraordinary collaborative efforts (Miles and Whitehouse, 2013). In the field of construction management, however, there is very limited work (Xue et al., 2010; Walker & Walker, 2015) that seeks to systematically unpack what collaboration is, in ways that are robust enough to guide empirical research and practice. To ground our discussion on collaboration, we weave together research in construction (Simatupang & Sridharan, 2002; Harty, 2008; Xue et al., 2010), mainstream management (Gray, 1985; Wood & Gray, 1991), and actor-network theory (Latour, 1987; Callon, 1991; Law, 1992), and propose a multi-dimensional definition of collaboration. This definition was presented earlier (see London et al., 2016) as a conceptual framework that suggests that collaboration is best understood as a multi-dimensional phenomenon with individual, systems, work, and market-related elements. Drawing from this conceptual framework, we define collaboration here as a pattern of interaction that emerges when a champion driven by a compelling vision and organizational citizenship behaviors (individual dimension) draws together human and non-human actants into sets of complex, heterogeneous networks of relationships (systems dimension) that cohere in ways that make the network stable, enduring, and convergent (work dimension). This collaborative network can also be expanded by aligning with other networks (market dimension).

We believe that this approach, of using a multi-dimensional definition instead of a precise and narrow definition of collaboration, has a distinct advantage: the main dimensions of the definition are flexible enough to sensitize users to a wide range of possible collaborative dynamics that are often overlooked by narrow definitions. However, in this study we seek to develop the definition further, specifically by identifying the key collaborative practices that comprise collaboration in housing prefabrication supply chains. We argue here that firms that have successfully implemented prefabrication have been supported by concrete sets of collaborative practices directed at creating and sustaining networks of organizations, people, objects, and texts linked together in complex and varied ecologies, to achieve different performance outcomes. Our second research question is therefore framed as follows: *(2) What are the collaborative practices that support successful prefabrication in housing construction supply chains?* In addressing this research question, we propose eight key collaborative practices that underpin successful prefabrication. We will show that the identification of these eight key practices contributes to theories on collaboration by enriching our multi-dimensional definition of the term. We will also show that the key collaborative practices are also a valuable contribution in that they form the basis of a rubric that aids empirical research and practice. We also argue that as part of future work, this rubric can be applied to our four case studies to show that different configurations of collaboration that can support housing prefabrication networks.

2 METHODOLOGY

2.1 *Qualitative case study techniques*

To address the research questions, we use qualitative case study techniques. We believe that they are well-suited to exploring phenomena in prefabrication supply chains, given that these are complex and, in Australian settings, little-explored. Qualitative case study methods are known to be appropriate in such contexts, as the finely-grained data that emerges from qualitative examinations has been known to contribute to theoretical development in areas that are relatively unexplored (Eisenhardt, 1989). The approach is also well-suited to examine collaborative practice in particular, given that much of the research on collaboration has focused primarily on quantitative approaches that can be quite limited in attending to nuances and complexities in collaborative practice (Hardy et al., 2003). We also note our selection of four cases was driven by the goal of achieving maximum variation, which increases generalizability of findings. This is because, taken collectively, the diverse cases provide insights on how different circumstances shape and are shaped by specific processes and outcomes (Flyvbjerg, 2006).

2.2 *Actor-network theory (ANT)*

In examining four case studies qualitatively, we used the toolkit of actor-network theory (Callon, 1999; Latour, 1987; Law, 1992), an approach founded on the premise that much of reality is the outcome of human and non-human actants interacting. Actor-network theorists argue that much of what we see in our everyday worlds – computer systems, entire countries, organizations, supply chains – are all "network effects" that emerge as objects, people, texts, and social systems interact with one another (Law, 1992). We believe that ANT is a robust methodological approach to employ in construction settings. First, construction projects involve not just one autonomous firm, but complex supply chains. As a network approach, ANT is useful in that it not bounded by the limitations of other approaches that depict the business organizations as autonomous units of production (Pryke, 2012). Second, construction settings almost always involve both human non-human entities (we use the term "actants"). Non-human actants include equipment, buildings and housing products. This is consistent with the ANT assumptions of heterogeneous networks and general symmetry (Law, 1992). Third, much of ANT research is grounded on the idea that networks develop in stages. A network emerges when a prime mover problematizes a situation, then seeks to enrol human and non-human actants into a network with the goal of solving this problem. Actants enrolled are envisioned to fulfill interlocking roles that support network goals. As these actants accept increasingly simplified roles defined relative to other actants' functions, the network becomes increasingly converged, and may stabilize to the point that its programs of action become difficult to reverse. Prime movers can also seek to expand network programs to include more actants, across time and across locations (Callon, 1999). The idea of network development through creation, convergence, stabilization, and expansion is useful in exploring dynamics in prefabrication supply chains. In particular, understanding these stages provides a processual perspective on how collaboration emerges. Such a perspective sheds nuanced understandings on collaborative phenomena in ways that static approaches cannot (Gray, 1985).

2.3 *Data gathering, analysis, and case descriptions*

ANT also provides methodological guidelines in terms of defining case contexts. For example, in discerning the boundaries of each of our four case studies, we were guided by ANT theorist Bruno Latour (2005), who argues that the boundaries of a network being researched can only be traced by "following the actors". In our case, "following the actors" led us to identify people, groups, equipment, objects, regulations, and texts as actants in each of the four prefabrication networks that we examined. Each case study, then, was not defined as a single organization, but as a network of people, organizations, objects and texts that were convened to carry out prefabrication efforts in housing. These networks we examined are at different stages: one at creation, two at the growth stage where entrepreneurial activity is emphasized over formalized

processes, and one at the maturity stage where formalized processes are foregrounded. Our primary data-gathering method was 24 semi-structured interviews with high-level managers from the focal organization of the supply chains under consideration, as well as their external partners such as architects and structural engineers. Interviews were fully transcribed and analysed thematically with the aid of NVivo. We also conducted observations, which allowed us to explore, among the other things, the roles of nonhuman actants like computer-numeric control machines, yards, and physical office spaces.

Brief descriptions of our four cases are summarized in Table 1. Drawing from actor-network theory, we note that each network is driven by a key actant, referred to by ANT researchers as the prime mover (Callon, 1999). In each of our cases, the prime mover is the focal organization that initiates prefabrication, convenes a network, and seeks to sustain it in order to achieve specific prefabrication outcomes. Because of its primacy in network creation, much of our case narratives and findings are framed around the work of this focal organization. That said, it is also important to acknowledge that these firms, while influential, are not autonomous. They are enmeshed in collaborative relationships in complex supply chains. We thus foreground these collaborative relationships in Part 2 of the analysis.

Table 1. Case descriptions.

Case 1	Focal organization is a diversified property group that was recently acquired by an international real estate company. It operates in New Zealand and in five Australian states, with staff numbering over 600. Focus is on initial use of prefabricated cassette flooring systems in 2012, triggered by concerns about worker safety and fall from heights.
Case 2	Focal organization is a regional builder of prefabricated transportable houses in two locations. Began as a family-owned business and while it has grown, it still remains very much relationship- and community-oriented. One location "manufactures' houses on an automated rail system, another builds these in a yard. Houses are then trucked to various locations. Employs than 100 employees. New general manager feels the company is "flying under the radar".
Case 3	Focal organization is a regional builder that has strong designer-builder relationships. Prioritizes customized housing projects using prefabricated components. Known for complex designs and exceptionally high energy ratings. Current employee base is less than 50. Recently restructured from a single company into three companies focused on specialized functions: design, project management, and prefabrication operations.
Case 4	Focal organization is a start-up in Victoria, Australia, with a mission of manufacturing precision-engineered wall and roof elements for timber frame construction, in a fully-automated factory using German technology. Awaiting more funding for equipment. Once set up, it expects that it a bespoke two-storey house can be assembled in two days with a team of five, a crane, and a single truck taking materials on a real-time basis to the building site.

3 ANALYSIS PART 1: FIRM TYPOLOGY, OUTCOMES AND PREFABRICATION

Table 1 highlights the characteristics of four different firms leading Australian supply chains in housing prefabrication. It is interesting to examine their characteristics relative to widely held beliefs about the "ideal type" organizations driving prefabrication. Earlier we noted current perceptions in prefabrication appear to be shaped by interlocking sets of assumptions: that prefabrication is all about achieving particular outcomes (low cost, high volumes) and pursuing specific strategies (mass production, standardization), and by extension this is taken to mean that prefabrication should be led by firms of a certain typology (large, capital-intensive). The uncritical acceptance of these assumptions could very well be a deterrent, potentially unfounded, for certain types of firms (small, labor-intensive, customization-oriented) considering a shift to prefabrication. Our empirical analysis of four prefabrication collaborative networks does in fact interrogate these limiting assumptions. In addressing the question (1) *What are the different firm typologies and outcomes that are linked to successful prefabrication?* our findings indicate that there are diverse typologies of firms that can drive prefabrication (Section 3.1), and that prefabrication is linked to a surprisingly diverse set of outcomes (3.2). We explore each of these points in the succeeding sections.

3.1 *Finding 1: there are multiple firm typologies that support prefabrication*

Our findings clearly suggest that is not just the capital-intensive, mass production-driven firm that is capable of convening and sustaining a collaborative prefabrication network. For example, Table 2 shows prefabrication networks can be successfully driven not only by large, established national developers, but also by small-and-medium enterprises with employee bases that do not go beyond 100, as well as new and emerging firms. Output-wise, prefabrication can be carried out successfully for detached as well as multi-storey, low- to medium-rise residential structures. Manufacturing operations can be designed around components, wall or flooring systems, or even entire houses. Such operations can be supported by full-scale industrialized processes (latter stages of Case Study 1, possibly Case Study 4), by parallel manual and factory operations across two locations (Case Study 2), or by basic equipment in a single factory (Case Study 3). In two cases, interviewees described how their "offsite" assembly of houses was literally being carried out by people working manually in a yard. Collectively these indicate there is no one "ideal type" of firm that can successfully lead a housing prefabrication supply chain.

Table 2. Typologies of firms that have driven successful OSM.

	CASE 1	CASE 2	CASE 3	CASE 4*
Focal organization	National developer	Regional builder	Regional designer-builder	Startup manufacturer
Firm life stage	Maturity	Growth	Growth	Startup
Market type	Housing	Housing	Housing and commercial	Housing
Housing type	Single-to-five storeys	Single storey, detached	Low rise to three storeys, detached	Low-rise, detached
OSM product	Floor system	House	Components	Wall and floor systems
Capital intensiveness	Low then high	Medium	Low	High
Size	MNC	SME	SME	Micro

(*) Successful in key areas of setup, but note it is still in startup stage

3.2 *Finding 2: there are diverse outcomes linked to prefabrication*

Our findings also call into question prevailing beliefs that the target outcomes of prefabrication are low-cost, mass-produced, standardized units. Qualitative data from our interviews show that prefabrication in each network was driven by complex sets of outcomes, and cross-case comparisons reveal interesting contrasts that suggest that prefabrication can be mobilized to pursue a surprisingly broad swathe of targets. Among all of the supply chains, Case Study 1 appears to be closest to traditional views of prefabrication; we describe it briefly and subsequently use it for comparative analysis. Case Study 1 interviewees who spoke about their pilot prefabrication project highlighted efficiency gains from their shift to the use of timber cassette floors. Specifically, efficiency gains included increased speed (four levels of the structure were built in six weeks; the building was completed one month early), manpower savings (from more than 20 to six), and cost savings (25% reduction in built costs per apartment). Prefabrication of timber flooring systems supported subsequent large-scale housing projects, including the construction of 48 two-storey homes completed swiftly over a six-and-a-half month period, instead of over the projected 12-month period. In light of these efficiency gains, expansion to Western Australia through projects using the cassette floor was pending. The role of capital equipment was significant. To support high volume house production, the cassette floor is now being produced in large quantities by a dedicated supplier that had invested heavily in equipment.

Case Study 1's priority outcomes, then, appear to be gaining new broad markets across the country through large-scale housing projects. This was made possible through reduced costs, and notably involved mass customization, not standardization. Interestingly, interviews also showed the main driver of the shift to prefabrication was not efficiency gains, as important as they turned out to be. Plans for prefabricated floor systems were launched mainly due to concerns about worker safety, as traditional flooring systems previously used posed health risks

and the risk of fall from heights. Exploring Case Study 1 provides an interesting benchmark that highlights some contrasts, as well as subtle differences, in outcomes pursued other case studies (see Table 3). For example, market expansion was prioritized in all cases, but in two cases "expansion" meant seeking broad markets, and in other cases it meant seeking niches. The emphasis on cost reduction also varied. Finally, specific supply chains were unique in the way that they championed specific outcomes. In Case Study 3, energy efficiency was very important; in Case Study 1, worker safety was a key driver.

Table 3. Outcomes pursued through prefabrication.

	CASE 1	CASE 2	CASE 3	CASE 4*
Focal organization	National developer	Regional builder	Regional designer-builder	Startup manufacturer
Emphasis on new market	High/ Broad	High/ Niche	High/ Niche	High/ Broad
Emphasis on low costs	High	Medium	Low	High
Targets for cost reduction	15-25% built cost	Make cost + delivery of transportable = to cost of site-built house	Prioritize quality, complexity, energy efficiency over cost	25%
Emphasis on complexity/ customization	Medium	Low	High	High
Strategy	Mass customization	Mass customization	High customization	High customization
Worker safety/ comfort	High	Medium	Medium	Low
Environmental sustainability	Low	Medium	High	Medium
Control over process	Low	Medium	High	High
Speed and efficiency	High	Low	High	High

*Potential, not actual.

4 ANALYSIS PART 2: COLLABORATION IN NETWORKS

Outcomes in construction projects are not dependent on strategies executed by autonomous actants, but on networks of actants bound together by collaboration. The link between collaboration and overall project performance has thus been the subject of a number of studies over the last two decades. Larson (1997), for example, used multiple regression analysis to explore the effects of independent variables of partnering (team building sessions, conflict identification, use of consultants to facilitate interactions, etc.) on dependent variables linked to project success (technical performance, control of costs). Baiden et al. (2006) identified dimensions of team integration and used this list to analyse teams of successful project managers who had won significant awards, assessing if such characteristics were fully, partially, or not achieved within such teams. Keung & Shen (2013) examined a list of collaboration-related factors that lead to what they refer to as network performance, using factor analysis to identify five critical dimensions: information exchange, communication, knowledge-sharing, a supportive culture and learning capabilities.

Despite attempts to link collaboration and performance, there are still significant gaps in more fundamental aspects of collaboration research. Specifically, there is very little work that has been done to define collaboration in ways that are robust enough to guide empirical research and professional practice. This has led Holti & Standing (1996, p. 5) to describe collaboration as not being "definable in its own right". The lack of a clear definition in turn could arguably be linked to Sabath & Fontanella's (2002, p. 24) comment that collaboration has "the most disappointing track record of various supply chain management practices introduced to date". Therefore our goal in this study is to contribute to this growing body of work specifically by analyzing collaboration in prefabrication supply chains through the identification of eight key

collaborative practices. Beginning with the premise that collaboration is a strategy for supply chain integration, we draw from actor-network theory to propose that an integrated supply chain is best understood as a converged network. Convergence has two elements: alignment and coordination (Callon 1991). To define alignment more concretely, we drew from ANT research that defines it as two elements: shared space and shared history (Callon, 1991). To define coordination more concretely, we found it helpful to draw from outside the discipline, from organizational theory. In his work in the area, Henry Mintzberg (1989) argues that coordination in and between organization takes place via six major mechanisms, depending on firm configuration. These six mechanisms, combined with Callon's (1999) two components of alignment, provide a tentative list of eight elements comprising convergence (Table 4, Column 1). We used these eight elements as preliminary themes for analyzing our interview data, specifically in categorizing participant responses to questions on what helped and hindered collaboration in prefabrication initiatives. As we moved between the initial eight elements and the data, we found that the 11 most frequently mentioned collaboration drivers mentioned by our interviewees were significantly aligned with the eight initial themes (see how Column 2 maps to Column 1).

Despite this alignment, we also found that our data could be used to further enrich the eight initial themes. In the initial set of themes, for example, no mention was made about the importance of a shared vision as foundational for successful convergence. However, both ANT and our empirical data clearly suggest it is important. ANT, for example, highlights this through its emphasis on a prime mover "problematizing" an issue in a compelling way (Callon, 1999). Our empirical data also suggests that a key driver for successful collaboration is the vision of a champion. These findings have led us to re-evaluate one initial theme, "direct supervision"; to reframe it was a broader concept, "champion"; and to include the element of "vision" as part of our definition of this modified theme. Another example is Mintzberg's (1989) reference to "standardized processes" as a mechanism for coordination. As an initial theme, it was helpful in that it sensitized us to the importance of explicated processes, but it was still potentially limiting. "Standardization" implies that all actants adhere to a common and fixed set of rules and specifications. Callon (1991, p. 148), however, suggests "a totally convergent network would thus be a kind of Tower of Babel. Everyone would speak their own language, but everyone else would understand them. Each one would have specific skills, but everyone would know how to use them".

In our case studies, for example, different actants in the supply chains achieved coordination not only through the imposition of a common set of narrowly-defined processes, although shared processes were certainly present at times. Coordination was on many occasions also achieved despite actants having to maintain certain domains of specialized processes. What was important was that other actants came to understand and uphold the different specialized processes that had to be carried out. As one interviewee pointed out,

> "...that's why we have people around the table, because I know I don't know engineering to the nth degree but I've got a fairly good understanding of it from a frame and truss point of view. But to draw on knowledge from these guys has given me a bit more confidence in making decisions in big meetings...It just builds... momentum and people catch on."

As we moved between the initial themes and the data, we thus sought to capture nuances and enrich these preliminary categories. The enriched themes are now the collaborative practices found in Table 4, Column 3. Following the identification of these collaborative practices, we then defined each one (Column 4) and explained how each one links to the different dimensions (individual, systems, work, and markets, see Column 5) of our definition of collaboration.

Table 4. Collaborative practices.

Concept based on literature	Theme based on interviews (1 = most frequent)	Collaborative Practice	Definition	Link to definition (individual, systems, work, market)
COORDINATION 1: Mutual adjustment (Mintzberg, 1993)	Willingness to mutually assist in problem solving (7)	Mutual adjustment and problem solving	Parties interact directly to solve problems in ways that generate mutually acceptable solutions	Systems: emphasis on how specific types of direct collaborative interactions can emerge in mutually-acceptable ways
COORDINATION 2: Direct supervision (Mintzberg, 1989)	Champion (2-3-4-5)	Champion	"Convenor" provides vision, drives chain through key organizational citizenship behaviors, and ensures roles and tasks of actants fit together	Individual: emphasis on how the characteristics and vision of a prime mover can set stage for collaboration
COORDINATION 3: Standardization of processes (Mintzberg, 11989)	Clear contracts, programs, (plans, drawings, specification) (6)	Explicit, coherent process standards	Procedures related to project tasks are documented and parties commit to adhering to these procedures	Work: emphasis on how procedures can be render collaboration durable through explication/ formalization, thus supporting collaboration
COORDINATION 4: Standardization of output (Mintzberg, 1989)	Clear (contracts, programs), plans, drawings, specifications (6)	Explicit, coherent output standards	Specifications of manufactured products are captured in technical drawings then shared with partners, who uphold these	Work dimension: emphasis on how output specifications can render collaboration durable through explication/, thus supporting collaboration
COORDINATION 3: Standardization of skills/ qualifications (Mintzberg, 1989)	Right people in terms of qualification (2-3-4-5) Right people in terms of attitude Optimal input from multiple disciplines (2-3-4-5)	Optimal mix of qualified people (skills as well as attitudes)	Expectations on the level of knowledge and specific attitudes of partners are explicated and upheld, and the right combination is achieved	Individual and systems: emphasis on how the characteristics of each actant as well as the mix of qualifications are foundational to collaboration
COORDINATION 6: Standardization of norms (Mintzberg, 1989)	Collective mindset (11)	Collectively upheld norms	Cultural values like commitment to quality or commitment to a prefabrication mindset are embodied and widely accepted	Systems, work, markets: emphasis on how norms and values become the basis for initial interactions, which can then become reified as a collaborative culture which can then be expanded to other domains

Table 4. Collaborative practices (continued).

ALIGNMENT 1: Shared history (Callon, 1999)	Shared history (2-3-4-5) Relationship orientation (8-9-10)	Long-term relationship building	Relationships are prioritized, relationships with partners are maintained over the long term	Systems, work: emphasis is on how collaborative interactions can be prioritized, then rendered durable over the long term
ALIGNMENT 2: Shared space (Callon, 1999)	Co-location (1) Communication mechanisms (use of IT) (8-9-10)	Shared physical/ virtual space	Co-location and frequent face-to-face meetings are prioritized, and at times supported by IT	Work: emphasis is on creating a "structure" that patterns interactions through material devices

Apart from defining the collaborative practices in Column 3, we also developed guidelines as to how each of the practices would look like if it were present in a specific context in a strong or weak way (see Table 5, Columns 2 and 3, for examples). This rubric, shown in part here, addresses our objective of developing a guide for empirical research and practice.

Table 5. Partial rubric for "high" and "low" level examples of collaborative practices.

Mutual adjustment and problem solving	...one of the things which we said to him was, 'We're going to work a program that's reasonable around your factory that it can produce. So let's work out what is reasonable that your factory can produce.' ... So it's working with them to understand what they can and can't do.	(Some parties are) are like, "Well, you fix it. You designed it, it's your responsibility." I said, "Well, that's not going to work because you need that entire collaboration and that entire cycle to occur."
Explicit, coherent process standards	So once you systematise every aspect of the construction, you need less - it's more of a repetitive task, which is easy to achieve quality and you can also have apprentices doing it.	And again when I started, there's no agreements in place, there's no pricing grid there's no SLRs (service level agreements), there's no any of those things. So I'm trying to bring to that, like get some agreements in place.

5 DISCUSSION AND CONCLUSION

In this study, we have made three contributions. First, we contributed to theories of collaboration. Specifically, the collaborative practices we identified (Table 4, Column 3) enrich the multi-dimensional definition of collaboration we presented earlier, not by adding new dimensions but by surfacing nuances within the different dimensions. Through literature and previous work we had previously defined the "systems" dimension as interactions and relationships between human and nonhuman actants. This study goes further by bringing to the fore specific characteristics that make such system interactions collaboratively viable: the importance of shared virtual and physical spaces, the power of mutual problem-solving, the importance of the mix of actant qualifications, not just individual qualifications, and the potency of a long-term orientation towards relationships. The "work" dimension is similarly enriched through the identification of important elements. An interesting finding, for example, is that "standardization" as traditionally defined by Mintzberg (1983) may be limiting as a mechanism for coordination. In this study, we have highlighted that it is not necessary for actants to share the same narrow set of standards to coordinate. What is needed is different actants being willing to explicate, understand and uphold diverse sets of processes in ways that allow the network to cohere.

As we draw these findings together, we can begin to propose a richer definition of collaboration. Space does not allow us to discuss this fully here, but collaboration can now be more fully understood as follows: a pattern of interaction that emerges when a champion driven

by a compelling vision and organizational citizenship behaviors (individual dimension) draws together human and non-human actants with *specific sets of qualifications into shared physical and virtual spaces*, creating opportunities for *interactions based on mutual problem-solving*, which then coalesce into complex, heterogeneous networks of relationships (systems dimension). These relationships cohere in ways that make the network stable, enduring, and convergent (work dimension), *primarily through explicated, coherent process and output standards as well as shared norms*. This collaborative network can also be expanded by aligning with other networks (market dimension).

A second contribution is methodological: we provide guidance on how collaboration in supply chains can be explored empirically, through the formulation of a rubric for the eight key collaborative practices. Future work can focus on applying this this rubric to our case studies.

Third, our empirical case studies have interrogated common assumptions that prefabrication supply chains can be driven only by one type of firm (large, capital-intensive firms doing high volume standardized production). Instead we have empirically demonstrated that it can be led by diverse types of firms. We have also shown that prefabrication as a strategy can be linked to a surprisingly broad set of outcomes. Particularly interesting is the finding that prefabrication can actually support, not hinder, customization.

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