Actor-Network Theory as a Processual Approach to Understanding Collaborative Practice in Innovative Construction Supply Chains

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ABSTRACT: *In this study we used actor-network theory (ANT) to develop a network-based, processual, heterogeneous view of collaboration in innovative housing construction supply chains. We selected an extreme case involving a supply chain experiencing multiple hindrances to collaboration, and qualitatively analyzed it at different developmental stages. Our findings suggest that ANT offers a fine-grained analysis that surfaces chains of conditions leading to successful collaboration, as well as tensions in collaboration (between integration and exclusion, disruption and stabilization) often overlooked by functional perspectives. We also argue that ANT's ontological assumptions about networks lead us to interrogate widely-held assumptions about collaboration itself. This leads to a broader conceptualization of collaboration that embraces, among other things, nonhumans as participants in collaborative work.*

Keywords: integration, lean production, networks

COLLABORATION AND ACTOR-NETWORK THEORY

Collaboration has been defined in management literature as a "cooperative, inter-organizational relationship that is negotiated in an ongoing communicative process, and which relies on neither market nor hierarchical mechanisms of control" (Hardy, Phillips, & Lawrence, 2003, p. 323). In the field of construction supply chains, a growing body of work has sought to deepen theoretical and empirical understandings of the concept, with research being carried out to operationalize it in the form of taxonomies of relationships (Walker and Walker, 2015), to identify barriers (Akintoye, McIntosh, and Fitzgerald, 2000), and to examine it empirically in the context of supplier-contractor interactions (Bemelmans, Voordijk, and Vos, 2012). Work has also been done to dissect collaboration into specific elements (Meng, Sung, & Jones 2011; Xue, Shen, & Ren 2010), and to explore how it drives project success (Kim, Kim, & Cho, 2015), influences cost (Jeong, Hastak, Syal, & Hong, 2013) and enables innovation (Ozorhon 2013).

While systematic theoretical and empirical work on collaboration in construction is emerging, it is far from well-developed. Our literature review suggests that the term "collaboration" in construction supply chain research is, more often than not, mentioned without being defined, or

simply implied without being clearly differentiated from other related terms like coordination, integration, or partnering (Ozorhon, Abbott, & Aouad, 2014; Oyegoke & Kiiras, 2009). This can arguably explain the observation that contractors in construction often do not know what the term means (Osipova, 2014) and the claim that "[c]ollaboration arguably has the most disappointing track record of various supply chain management practices introduced to date (Sabath & Fontanella, 2002, p. 24). Our goal for this paper, then, is to contribute to a more robust understanding of collaboration in construction supply chains, not by formulating single definition of collaboration, but by using an approach that can draw out its complexity in ways that will aid in empirical research and in guiding practice. We are interested specifically in defining collaboration in ways that take into consideration three important characteristics of construction contexts as settings for collaboration: they are (1) permeated by supply chains, thus the dominant arrangement is complex webs of relationships rather than autonomous firms (Pryke, 2012); (2) characterized by tension between permanence and provisionality, given that temporary supply chain relationships have been found to be embedded in more permanent ones (London 2008); and (3) characterized by interactions between humans and non-humans (Harty, 2008), the latter including equipment, buildings, and written standards. We argue that these characteristics thus call for an understanding of collaboration that is *network-based, processual,* and *heterogeneous*. A network-based view of collaboration is based on the assumption that collaboration is a response to complex problems that no single actor can address (Gray 1985). Such a view, we believe, is well-suited to construction contexts dominated by supply chains, as it addresses the limits of other conceptual approaches that emphasize the firm as an autonomous unit of production tend to be incomplete and limiting (Pryke 2012). A processual view of collaboration is based on the premise that collaboration within a certain domain can be more fully understood by examining the developmental phases of that domain, then "considering the conditions [for collaboration] necessary to move through each developmental stage" (Gray 1985, p. 916). Processual perspectives thus shed light on what facilitates, stabilizes, or hinders the emergence of collaboration at various phases of a domain's development, in ways that more static approaches cannot. Finally, a heterogeneous view considers both humans and nonhumans (Law 1992) as actors in collaboration. The specific network approach we use here is actor-network theory (ANT), a choice we justify shortly. The research

question we seek to address is: *What is the value of actor-network theory in developing a network-based, processual, heterogeneous understanding of collaboration in innovative supply chains?*

Actor-network theory is a theoretical and methodological approach that suggests that much of reality can be understood as human and non-human actors interacting in heterogeneous networks, thus leading to outcomes (Law, 1992; Latour, 1987). There are three reasons why we believe that ANT is a fitting framework for analyzing collaboration in construction supply chains. First, ANT emphasizes ideals such as network coherence and network convergence, which are consistent with the collaboration ideal of achieving supply chain integration. Implicit in this discussion, therefore, is the assumption that the conditions that give rise to stable, converged and expanding networks can be understood as conditions that give rise to integrated supply chains held together by collaboration. Second, ANT is processual in that it proposes that networks develop in stages. This provides an organizing frame for understanding the emergence of collaboration, as the conditions for it are identified at every phase. ANT theorists specifically argue that the authoring of a network begins with a primary actor, referred to as the *primum movens*, prime mover, or the perceived "first cause" of a chain of interactions. The prime mover begins by identifying a problem and framing a solution and then launches strategies that aim at enrolling actors into a network that will address the problem. These strategies may or may not be successful. In cases where actors are successfully enrolled and a network is created, processes are then set in place to achieve network convergence in the form of an integrated, punctualized network (Law, 1992), as well as network stability. Work is also done to expand the network across time and across locations. This process is referred to by Callon (1999; 1986) as translation.[1] These stages thus allow us to consider how networks not only change, but also persist in stable forms. A third reason we employ ANT is that it is based on the assumption of general symmetry, which treats humans and non-humans as ontologically equal. This means that any study on collaborative networks framed from an ANT perspective must consider non-human actors as participants in collaborative work. This is an important consideration, given that construction projects often involve nonhuman entities, but their role in collaboration has been given limited attention.

[1] Translation is explained in greater detail in Figure 2 (Columns 1 and 2).This figure is in the results sections as it also incorporates findings.

General symmetry has potentially profound implications, as it interrogates the widely-held assumption that collaboration is purely human work (Ribes et al. 2010).

Our specific interest is in construction supply chains that are collaborating on housing construction innovations. There are important links between collaboration and innovation, as studies have shown that successful innovative outcomes often emerge from firms using different kinds of inter-organizational collaboration (Faems, Van Looy, & Debackere, 2005). Research has also shown that understanding different stages of innovation (for example the five stages as proposed by Rogers, 2003) can be a useful conceptual device in unpacking *intra*-organizational collaborative activities that take place within innovative firms (London & Siva 2011). That said, the complexities of the construction industry have at times made innovation in this context difficult to understand (Harty, 2008). We therefore focus on the emergence of collaboration in construction supply chains using innovative offsite manufacturing techniques. We do so based on the premise that periods of innovation usher in opportunities to examine actors' heightened efforts at forging or re-forging collaborative interactions, as they attempt to introduce large-scale change in a conservative industry.

METHODS

We use ANT as an analytical device to examine supply chain networks in different stages of development and to identify conditions that enable the network to move through these stages. Our research involves four qualitative case studies of different housing construction supply chains across Australia, all undergoing significant periods of innovation through the use of offsite manufacturing, leading to network creation due to startup activities, or network recreation due to large-scale change. Figure 1 summarizes the characteristics of the case studies and demonstrates that case selection was carried out to achieve maximum variation (Flyvbjerg, 2005).

Insert Figure 1 about here

Data was gathered primarily through semi-structured interviews lasting one hour each. A total of 22 interviews have so far been conducted. Interviewees were selected through an iterative process negotiated between the research team and case sites. At the point of obtaining access to case sites, we provided written documents to a contact person outlining the nature of the project, the types of

questions we sought to address, and a set of guidelines for participation, among them the guideline that we were looking for interviewees (internal managers and external partners) who had had meaningful involvement in offsite manufacturing projects. In each case, our contact person then provided us with a list of people to interview, which we then reviewed and adjusted as necessary. Individual decisions on whether or not to participate were communicated only to the research team, not to the coordinator, to maintain confidentiality. The resulting list always included the CEO (or, in the case of the multinational in Case Study 1, the project manager of the large-scale project we were analyzing). The research is ongoing and we have used this first iteration as a basis for identifying new people to interview, as well as other people to revisit at a later time, an approach consistent with the snowball technique. Interviewees' and organizations' names were anonymized and are known only to the research team.

Interview data were transcribed and analyzed thematically using NVivo. We began thematic analysis using a preliminary set of four categories: drivers and barriers to OSM, as well as drivers and barriers to collaboration in OSM projects. We moved iteratively between ANT literature and empirical findings on facilitators/ hindrances to identify possible conditions linked to collaboration at each stage (see Figure 2, Column 3). For example, a recurring facilitator of collaboration was "strong champion"; from an ANT perspective, this would translate into a strong prime mover. Another recurring facilitator was "hiring people with the right qualifications"; from an ANT perspective, this would translate into identifying the right attributes of actors and enrolling actors with these attributes. As we moved iteratively between the themes and the data, we progressively refined these, and currently have a list of four categories and 100 sub-themes. These have been presented twice to a panel of industry partners, who collectively serve as part of the project's steering committee.

Due to restrictions on paper length, we will limit our detailed qualitative discussion to Case Study 2, a network of companies that focuses on the construction of traditional and transportable houses. The focal company within this case study is Company B, a builder that operates from two locations in the state of South Australia. We chose Company B because of its potential for yielding insights as an extreme case. Flyvbjerg (2005, p. 229) suggests that a single, carefully-selected single case study can provide significant insight and that deviant cases (extremely good or extremely

problematic) can provide the richest information, "activat[ing] more actors and more basic mechanisms in the situation being studied" as compared to typical cases. Following this argument, we chose Company B because among all four cases, it presented the most hurdles to collaboration and could therefore be the most potentially insightful in exploring why and how collaboration can fail.

Company B has recently undergone two significant changes. About four years ago, it developed a concrete slab for its transportable housing line that had a distinct affordance: it allowed transportable homes to be built at ground level, instead of half a meter higher above ground level like most transportable homes on the market. This triggered change in the form of new market niches and in new work processes that would, at least in theory, have to be designed to support its production. In October 2014, the company hired a new general manager. This particular change triggered a new cycle of network building for Company B and its partners. Using ANT and its concept of network stages (creation, convergence, stabilization and expansion), we examine this network development process generally and from there identify conditions that facilitated and hindered collaborative practice.

RESULTS

Our findings show Company B has struggled at all stages of network development to develop a collaborative network. ANT provides a framework for identifying hurdles encountered through the network development process and these hurdles in turn point to conditions that have largely hindered the emergence of a collaborative supply chain. A few facilitators also emerged. These are summarized in Column 4 of Figure 2.

Insert Figure 2 about here

Stage 1: Network (re)creation

Empirical data indicates Company B was undergoing an intense period of network creation, or more appropriately, network recreation, as the prime mover sought not to build a new network from scratch, but to reopen an existing, seemingly stable network (Law, 1992). The prime mover in

this case was the new general manager, hired by the original company owners/ managers because Company B was seeking leadership in the regional market. Our analysis suggests a number of key hurdles at this stage.

Stage 1(a): Prime mover and problem definition

One major hurdle to collaboration was the "prime mover" position being ambiguously perceived. The general manager herself shared that was "the outsider" entering an established domain:

> I think the greatest barrier is myself…Because I am the girl from Adelaide. .. [and it's like they say] you come in here and - - - [w]e've been doing business like this for, you know. (General Manager, Company B)

A second challenge to collaboration was the manner in which problematization was carried out. The general manager saw the business as one "flying under the radar" because "it hasn't kept up with itself", mainly because of its lack of formalized systems, processes and structures. The process of "problematization" thus involved the general manager communicating to staff that her priority was the professionalization and transformation of programs, policies and procedures. This pronouncement was met with resistance. Employees were used to the informal practices of a formerly family-owned business, and were reportedly non-compliant with the proposed changes. To complicate matters further, their superiors did little to push for compliance. The general manager recalled:

> I've put a lot of pressure on the team because I'm talking about budgets and goal setting and reporting, and what not. Anyway, so that there's…one of the ladies, she will – I'll push for something and ask for something, can we get…[and she says] why does she effing want this... Now, her manager …doesn't pull her into line, doesn't enforce professionalism, doesn't really do any of that. (General Manager, Company B)

Resistance could have also been deepened by the fact that the language used was framed in the discourse of revolutionary change ("new" processes, "new" systems and "new" ways of doing things) instead of in the less risky discourse of gradual, incremental change.

Stage 1(b): Interdefinition of actors

Another challenge in the creation of a collaborative network can be discerned when we explore how "interdefinition of actors" took place. Interdefinition involves actors taking on roles relative to one another, oftentimes exchanging complex roles for simpler ones (Callon, 1999). In this case, there was limited room for interdefinition because the network was not being built from scratch, but was in fact a stable network being recreated (Law, 1992). The general manager was hamstrung to

the extent that the existing network already had underperforming internal employees and external partners enrolled. Network recreation, then, was implemented amidst constraints; nevertheless it took place tentatively in two ways. First, a certain degree of purging was planned in an attempt to remove at least some of the underperforming elements. At the time of the interview, retrenchment efforts were very quietly launched, with advertising for new people done very discretely. A second strategy, targeted at actors who would remain, was to recreate a network with more qualified actors by redefining existing relationships. This can be understood as a process of transitioning partnerships founded on one set of criteria (for example an informal, relationship-driven partnership) to partnerships that would now be based on another set of criteria (a more formal, performance-driven partnership). We discuss this in the next section.

Stage 1(c): Interessement and enrollment

The network of external partners that was in place was mainly one that had been developed by owners over time. Relations were mostly sound, but were founded mainly on a shared history and relational goodwill rather than on economic performance. An owner and long-term manager shared that his philosophy in partner selection was not to "chase the dollar" because "you sort of burn those relationships." The result was an emphasis on long-term relationships, but sometimes at the cost of not obtaining the "best price." The company's newly-hired sales director observed:

> …one of my bug bears with [owner]… is he won't switch suppliers sometimes. When I know we can get it cheaper … [he says] no, he's a good guy, he's honest, he looks after me, the price, he's around the mark, he's not, you know, so we'll stick with him... you've got to love [owner] for it because he's just about relationships but, you know, just got to find that happy balance, we're a bit too happy families at the moment… (Sales Director, Company B)

From an ANT perspective, there was now a need to detach these partners not from the network itself, but from their old identities of simply being "loyal partners" who did not always give the best price. There was also a need to reconnect them with new identities as "professional partners." ANT theorists refer to this stage as *interessement,* when potential network enrollees are caught between two possible identities and the prime mover attempts to move them away from those that compete with network formation (Callon, 1999). The general manager tried to execute this shift by making the rounds of partners, reframing priorities along the lines of "relationship is important but so

is profit", then instituting formalized agreements with clear expectations and standards. The outcomes of this effort remain to be seen. Nevertheless the general manager described the effort this way:

> I am very conscious of, now, that I'm bringing in price agreements, service level agreements, and all of those things, and I'm very conscious of how I deliver the message to the supplier and to the business.…the conversation is, I value the relationships and I appreciate those, but at the same time again my instruction is to make a profit. (General Manager, Company B)

Stage 2: Network convergence

In one sense, actors' shared history was making it difficult to recreate new network roles, but shared history did have one advantage: it bred loyalty, not to the new prime mover, but to former owners who were still managers. A shared history is linked with alignment, which is one of two key factors leading to network convergence (Crawford, 2005). In this case, shared history appeared to compensate at least in part for the weaknesses that emerged in the rocky process of network creation. One manager who had been with the company for many years noted,

> …our trades are willing to travel 50 kilometers from here within that rate now and they understand it's just we're supplying them a constant supply of work. Like, I've had a carpentry gang here that hasn't looked for work for four years. Haven't had to go anywhere else and they're loyal to us now as well. (Construction Manager, Company B)

Alignment was also achieved, to a certain extent, by a shared space. This was possible because a significant part of design and construction work was done in clearly-defined locations, allowing designers, builders, project managers, and sales teams to converge at a single site. This allowed questions to be answered immediately and problems to be addressed quickly:

> Just everybody's here. It's a minute answer if you need it. You've got the draughtsman here, you've got the sales, you've got the selections. (Design Contractor, Company B)

Another point to take note of, though, is that convergence is not just about alignment, but also about had another dimension, coordination (Crawford, 2005). Coordination, in turn, is linked to codification (for example capturing standards in formal documents) and compliance with convention (for example people following written standards). Coordination at Company B was weak mainly because of the absence of formalized systems and codified knowledge. Externally, the lack of explicit agreements with suppliers made it difficult to keep them accountable:

> …when I started, there's [sic] no agreements in place, there's no pricing grid, there's [sic] no SLRs [service level reports], there's no any of those things. So I'm trying to bring to that, like get some agreements in place. Because I want to understand timeframes, for me, it's

> about, time costs quality, and get that, and less of the handshake. I don't want to burn the relationship, but I want to find the boundaries in a relationship, too, that we need. (General Manager, Company B).

Internally, there were also difficulties in coordination because information-sharing was sluggish, dependent on paper-heavy systems. Network convergence, then, could not be described as strong.

Stages 3 and 4: Network stabilization and expansion

There are two possible reasons why Company B struggled with stabilizing its network. ANT researchers argue network stabilization is greatly facilitated by the use of "immutable mobiles" (Law, 1992), devices such as texts or objects which become inscribed with network programs of action. The acknowledgement of the role of immutable mobiles carves out a space to consider the role of non-human actants in facilitating network convergence. An example of this can be seen when a routine manual process becomes inscribed in an online site, forcing users in different locations to comply with a predetermined set of steps that eventually appear to become reified and taken-for-granted as a process. When such an inscription allows the program of action to be carried to another place, it is "mobile"; when the inscription persists through time without having to be changed, in becomes "immutable" (Lower, 2005). Immutable mobiles stabilize network activities in the way that technologies make social systems durable (Latour, 1991).

Company B had a number of such devices that could potentially make work processes stable. To start with, it had simple, standardized housing designs that designers and builders shared. This allowed for routinized processes, at least as far as building operations were concerned. On the business side, Company B had begun building this repository of documents (checklists, service level agreements) that could be "transplanted" in other settings and thus facilitate expansion. These, however, were exceptional; more broadly, there was a lack of formal systems in areas like human resources, finance and accounting that made stable routines difficult to achieve. Employees carried out processes in largely informal ways. When attempts were made to formalize these, monitoring proved difficult as a single pool of people was tasked to check for compliance across various locations. The outcome was the lack of structures that could have made collective work stable:

> …we allow bad behaviours. So there's an accounts lady there that, because I have the audacity now, because they never were doing budgets, we never were doing budgets, we

> never were reports, financial reporting…You finish one month, then you might get those results two to three months later. (General Manager, Company B)

The lack of formal reporting along with the need to operate across two different locations therefore made it difficult to monitor deviations of actors from stable processes and hampered the ability to step in and make corrections as needed.

The lack of stability in the network also made it more difficult to *expand* collaborative network routines to other locations. First, the process of translation that we discerned in early stages of network development suggests that a high level of convergence has not been achieved. In the case of Company B, significant work is still being done to get the local network to function as an efficient, punctualized network and this could arguably mean there are fewer resources to deploy towards expansion. Second, immutable mobiles could not even stabilize local contexts, thus using them to stabilize other less proximate settings did not seem likely at this time.

SUMMARY AND CONCLUSION

Our findings suggest that an ANT approach to understanding collaboration is valuable in four ways. First, it supports a processual view that traces network development through stages and thus facilitates the identification of sets of conditions that facilitate and hinder collaboration at each stage. Second, ANT surfaces the tensions that make collaboration challenging, tensions that are often overlooked by functional approaches to collaboration. For example, our analysis suggests building a collaborative supply chain involves not just strategies of integration (enrolling actors to address a single problem) but also strategies of exclusion (cutting away actors or competing identities). Collaborative work also calls for strategies of stabilization (through immutable mobiles) as well as destabilization (triggering trials of strength that reopen and interrogate existing punctualized networks). Challenges arise, then, in terms of navigating the tensions that arise from these contradictions. These tensions also point to the possibility of exploring how concepts like conflict, exclusion, and controversy could actually be instrumental in ultimately achieving collaboration.

A third insight that emerges from using ANT as an approach has to do with the definition of collaboration itself. A common view of researchers studying collaboration is to assume that

collaboration is human work, and that any coordination and interaction that takes place involves "decision-makers (i.e. human beings) from economic institutions based on a division of labor" (Halldorsson et al. 2007, p. 286, emphasis ours). Corollary to this is the view that non-human elements such as technological artefacts serve, at best, as passive mediators of human communication (Ribes et al. 2013, p. 10). ANT is different in that it gives equal ontological status to human and non-human actants linked in heterogeneous networks (Law 1992), leading Latour (2005, p. 72) to argue that objects "might authorize, allow, afford, encourage, permit, suggest, influence, block, render possible, forbid and so on". In our case study, we have begun exploring the collaborative work that has been done by simple house designs, yards, and checklists. The yard, for example, does the work of stabilizing collaboration by anchoring it in a specific place; the house designs and checklists facilitate collaboration by explicating standards that become a precisely-defined interface between different units or groups of specialists. Such standards and checklists are not seen as passive; they are active in that they exert a disciplinary force over what processes, actions, and deviations are acceptable, and which ones are not. On a related note, we can also argue that the absence of specific non-human entities could very well be contributing to collaborative failures. The absence of objects like "agreements, service level reports, and pricing grids", as noted by the new general manager, means that there is a lack of immutable mobiles that could theoretically serve the purpose of inscribing collaborative patterns of interaction in ways that could render them stable, and capable of being expanded to other locations. The acknowledgement of the role of non-humans in collaboration thus paves the way for interrogating definitions of collaboration that foreground only human and social actors. Finally, an ANT approach calls into question oversimplified definitions of collaboration that are often confined to social relationships on the same scale ("inter-organizational" or "interpersonal"). The webs of interaction (person to group, person to object, group to document) surfaced by ANT in this study leads us to reconsider neat, linear supply chains as units of analysis. Instead, it adds weight to arguments that the idea of collaborative "networks" can more fully capture the intricacies of interactions among humans, social groups, objects, and texts embodied in the form of standards.

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Figure 1. Case Studies and Characteristics.

FIRM CHARACTERISTICS												
SIZE/ NATURE OF ORGANIZATION	STARTUP				SMALL/ MEDIUM ENTERPRISE				MULTI-NATIONAL			
				C4		C2	C3		C1			
LEVEL OF OSM	COMPONENTS				SYSTEMS (WALL, ROOF, FLOORING)				COMPLETE HOUSES			
			C3		C1			C4		C2		
NATURE OF PRODUCT	HOUSING, DETACHED, SINGLE STOREY OR LOW RISE				HOUSING, SINGLE TO FIVE STOREYS				HOUSING AND COMMERCIAL			
		C2		C4	C1						C3	
COMPLEXITY OF DESIGN/ LEVEL OF CUSTOMIZATION	LOW: OSM PRODUCT DESIGNS SHOW MINOR VARIATIONS				MEDIUM: MASS CUSTOMIZATION				HIGH: DESIGNS VARY FOR EVERY PROJECT			
		C2			C1						C3	C4
LEVEL OF EXPERIENCE/ LENGTH OF HISTORY WITH OSM RELATIVE TO FIRM LIFE	LOW: ZERO OR SMALL PORTFOLIO OF COMPLETED OSM PROJECTS				MEDIUM: GROWING PORTFOLIO OF OSM PROJECTS; TRADI-TIONAL BUILDS DOMINATE				HIGH: SUSTAINED HISTORY OF CARRYING OUT OSM PROJECTS			
				C4	C1	C2					C3	
INFLUENCE OF A CHAMPION IN PUSHING FOR OSM	LOW: OSM NOT PUSHED BY A KEY PLAYER				MEDIUM: OSM DRIVER HINDERED BY OTHER FACTORS				HIGH: PUSH BY A KEY OSM CHAMPION IS DECISIVE			
						C2		C4	C1		C3	
EASE OF TRANSITION FROM TRADITIONAL MINDSET TO OSM MINDSET	LOW: MOVE TO OSM WAS CHALLENGING BECAUSE LONG HISTORY IN TRADITIONAL BUILDING				MEDIUM: MOVE TO OSM WAS NEW BUT EASED BY A CULTURE OF INNOVATION				HIGH: FIRM WAS ESTABLISHED AS "DOING OSM" FROM THE START			
	C1			C4		C2					C3	

"C" STANDS FOR "CASE"; C1=CASE 1

Figure 2. Network Stages, Conditions for Collaboration and Findings.

STAGE OF TRANSLATION	CHARACTERISTICS OF STAGE	CONDITIONS THAT FACILITATE COLLABORATION	FINDINGS IN COMPANY B (F-facilitator of collaboration; H-hindrance to collaboration)
(1) NETWORK CREATION	• PROBLEM DEFINITION. The prime mover identifies a problem and a corresponding solution, thus putting itself in the center. • INTERDEFINITION OF ACTORS. The prime mover identifies potential actors who might be interested in the problem and seeks to enroll these, attributing characteristics and interests to the actors in the process These attributions may not be accurate nor even collectively coherent. • OBLIGATORY POINTS OF PASSAGE. The prime mover seeks to demonstrate that disparate players can only meet their goals if they form an alliance. • *INTERESSEMENT*. Actors struggle with multiple identities, only some of which would allow them to be part of the network. The prime mover seeks to cut these actors away from identities that compete with the network being formed (Callon, 1999). • ENROLLMENT. An actor commits to fulfill a very specific role relative to others. The role is shaped by processes of juxtaposition (an actor forms an identity only relative to others) and simplification (its possibilities for acting become limited) (Callon, 1986). Actors therefore change when they become part of a network.	• Strong prime mover • Compelling problem • Identification of the "right" actors with the "right" characteristics • Willingness of actors to form an alliance • Actors being cut away from competing identities • Actors being willing to change (for example fulfil simplified roles) in order to be part of the network	• Prime mover occupied tenuous position; role as spokesperson questioned (H) • Problem framed in an unconvincing way, making enrolment into a collaborative network difficult (H) • Problematization linked to revolutionary, rather than evolutionary change (H) • Interdefinition of actors could not be fully carried out due to existing roles (H) • Underpeforming actors could not be readily cut away from the network (H) • Existing identities of partners as "friends" could not be readily cut away to give way to more professional identities (H)

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STAGE OF TRANSLATION	CHARACTERISTICS OF STAGE	CONDITIONS THAT FACILITATE COLLABORATION	FINDINGS IN COMPANY B (F-facilitator of collaboration; H-hindrance to collaboration)
(2) NETWORK CONVER-GENCE	• Convergence is linked to a number of factors. • Alignment is achieved when actors share space and history. • Coordination is achieved when actors adopt conventions prescribed by the network). • Irreversibilisation is achieved when routines are set up and are difficult to change (Crawford, 2005).	• Alignment is present • Coordination is present • Irreversibilisation is present	• Shared history leads to alignment, at least in terms of keeping partners loyal, albeit underperforming (F) • Coordination hindered by lack of formal conventions and hurdles in information-sharing (H)

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STAGE OF TRANSLATION	CHARACTERISTICS OF STAGE	CONDITIONS THAT FACILITATE COLLABORATION	FINDINGS IN COMPANY B (F-facilitator of collaboration; H-hindrance to collaboration)
(3) NETWORK STABILIZATION	• As networks converge, they stabilize into routines (Creswell, Worth, & Sheikh, 2011). • They may even reify over time to the point that a heterogeneous network begins to appear as a single, coherent and homogenous actor instead, a simplification process known as punctualization (Law, 1992). • However, ANT proponents are careful to point out all networks are contingent and can be destabilized at any time (Law, 1992).	• Routines stabilize to the point that they are reified and taken-for-granted	• Simple, standard house designs make it easy to replicate collaborative work patterns across locations (F) • Checklists are being formulated to replicate collaborative work patterns across settings (F), but these are embryonic (H) • Routines fail to stabilize because employees do not comply with established patterns and the lack of monitoring exacerbates this (H)
(4) NETWORK EXPANSION	• A network's stable routines or programs of action can then be inscribed them into devices that in effect extend the reach of a network: texts, oral messages, technological artifacts like machines, social artifacts like institutions. • When a program written into an inscript persists over time without having to be changed, the inscript is described as "durable". • When an inscript can expand the reach of an actor over space, the inscript is described as "mobile." • When an inscript that is both highly durable and highly mobile is called an "immutable mobile." • The more immutable a mobile is, the more irreversible it becomes and the stronger (harder to oppose) the inscript is (Lower, 2005).	• Immutable mobiles are deployed	