A MULTILEVEL ANALYSIS OF COLLABORATION IN OFFSITE MANUFACTURING SUPPLY CHAINS USING ACTOR NETWORK THEORY

Kerry A. London[1*], Zelinna Pablo[2], and Malik Khalfan[3]

[1, 2, 3] *School of Property, Construction and Project Management, RMIT University, Melbourne, Australia*
[*] *Corresponding author (kerry.london@rmit.edu.au)*

ABSTRACT

The Australian housing industry is failing to meet demand. The current housing construction model is characterized by craft-based on site construction techniques resulting in fragmentation. This has created inefficiencies in the construction process, with average construction time increasing 40 per cent over the last fifteen years. Construction supply chain integration has been proposed as an overarching industry solution, but there is little evidence that practices have changed. An example of a supply chain integration solution is off-site manufacturing. Past research indicates that manufacture in a factory using production engineering techniques will ensure a level of efficiency, innovation, quality and accuracy that onsite construction cannot match. However, it is suspected that the adoption of innovative offsite manufacturing is constrained by the lack of collaboration at all levels in the industry and across many of the organisations involved. Understanding how to achieve this is a complex and difficult problem, in part because of the range of organisations involved; resistance to adoption of new techniques; the adversarial culture of the industry; and dispersed power across various organisations. This paper presents a new theoretical framework for collaboration developed from a critique of offsite manufacturing literature and collaboration theory. We frame our multilevel analysis using actor network theory, which will enable an analysis of interactions between, and influence of, housing developers, designers, unions, industry organisations and government agencies. We use qualitative case study techniques based on elected exemplars which utilise novel construction methodology requiring a significant collaborative effort involving a mix of offsite and onsite manufacturing. This is a three study and we are currently in phase one of the first year focussed on theory development.

Keywords: *industrialisation, supply chain theory, collaborative ecologies*

1. BACKGROUND

Industry fragmentation and craft-based manufacturing are oft-cited causes of construction inefficiency in the housing sector (Blismas et al. 2005; BEIIC 2012). A solution is offsite manufacturing (Hampson & Brandon, 2004), which generally offers many advantages over the current construction approach (Goodier & Gibb 2004) that can be broadly summarised into two categories; 1) product quality control and 2) process efficiency (Blismas & Wakefield 2009). Australia lags behind other countries in adoption of OSM, which is seen to be complex and difficult because of the range of organisations involved and the inertia against change in a traditionally oriented industry, the adversarial culture and dispersed power across various organisations (Fernie & Tennant, 2013). Barriers to integration occur at sectoral and organisational levels (London 2008). Collaboration for innovation is challenging because of the difficulties in creating positive, trusting and influential relationships (London & Siva 2012). We aim to analyse the conditions that seemingly create successful supply chain integration to support innovative offsite manufacturing and develop a novel collaborative practice based implementation model.

1.1 Offsite manufacturing

Offsite manufacturing (OSM) is a production technique in which prefabricated components of a building are manufactured in a factory and transported to the site for erection and assembly. OSM requires re-engineering of the entire project development process, since traditional construction is achieved mostly through on-site activities. The shift to OSM within the construction industry has been linked to several factors, including the emergence of knowledge-based environment and rapid change in information technology; changing marketplace and competition; the need to address traditional construction skill shortages; and the push to ensure time and cost certainty and achieve high quality (Khalfan et al. 2014). Pan and Goodier (2012) confirmed that OSM adoption brings benefits to the construction projects including reductions in time, defects, health and safety risks, environmental effects, and whole-life cost and increase in sustainability, productivity, whole-life performance, and

profitability. Chandler (2014) foresees an increase in OSM utilization up to 15-20% within the Australian Construction Industry by 2023. However, there are numerous barriers to uptake. A key overarching constraint to uptake is that OSM is perceived to require extraordinary levels of collaboration (London & Siva 2012).

2.0 TOWARDS A COLLABORATION MODEL FOR SUPPLY CHAINS

Our purpose for this paper is to explore offsite manufacturing as an exemplar of supply chain integration practice through a multi-level (sectoral and organizational) analysis, with a specific focus on collaboration. There are numerous and interchangeable definitions for supply chain integration, management or procurement in both construction literature and various other disciplines (London 2008). For purposes of this study, supply chain procurement is the strategic identification, creation and management of critical project supply chains and the key resources, within the contextual fabric of the construction supply and demand system, to achieve value for clients (London 2008). Supply chains have emerged in various configurations: in orientation and degree of integration (Frohlich & Westbrook, 2001); in "length" (Mentzer et al. 2001); in scope of process clusters covered (Lamming 1993); and in terms of level of management and implementation (Childerhouse & Towill 2011). We explore OSM contexts to investigate the degree with which one organization can feasibly 'manage' and 'integrate', and we analyze which 'actors' are influential in a 'chain' that appears to be well integrated. As London (2008) observed using an industrial organization lens to develop construction supply chain economics theory, the significance of the item being transacted and the nature of countervailing power between the supplier and customer are embedded within both a project market and an industrial market that are constantly in tension. The nature of this tension is influenced by structural and behavioral characteristics including various 'actors' or agents; firm-firm behavior; the project market; the industrial market; 'commodity' type and complexity, interdependency and multiplicity of relationships. This tension can inhibit or enhance capacity for supply chain integration and innovative transformative change (London 2008). We argue here that a mechanism that propels chains towards integration while addressing many aspects of this tension is collaboration.

Collaboration is unavoidable in discussions involving supply chains, which are characterized by significant levels of interdependence between units. Authors have argued that under such conditions of interdependence, collaboration is "the only viable response" (Gray 1985, p. 916). Collaboration has been discussed as the preferred paradigm for supply chains, as opposed to competitive paradigms (Simatupang & Sridharan 2002); as a degree of enmeshment, with a "collaborative" culture being understood as the most integrated as a strategy for repositioning on a supply chain (Nordin et al. 2009); and as a set of attitudes and practices (Xue et al. 2010).

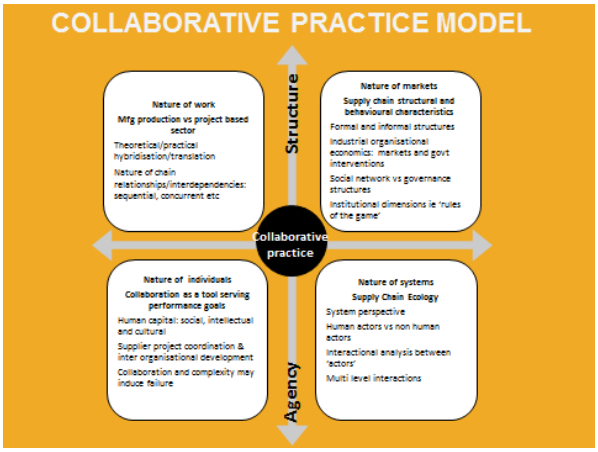

Figure 1. Trends in collaboration based on reviews.

There is no single definition for collaboration. Some writers have mobilized it as a general term, for example as any relationship between "two or more stakeholders pooling resources… or 'appreciations' in order to address problems extending beyond the domain of a single entity/ organization" (Gray 1985, p. 912). Others have defined it more narrowly, as distinct from cooperation and coordination (Mandel & Keast 2007), or as a type of cooperative relationship that does not depend on the market or on hierarchical control (Hardy et al. 2003, p. 323). We contend that a robust definition of collaboration must be cognizant of the nature of competition and its underlying structural and behavioural conditions, otherwise the motivation for collaboration cannot be fully comprehended. Given the salient link between collaboration and supply chains, we propose that an enriched understanding of collaboration will lead to, and is in fact a prerequisite for, further development in the field of construction supply chains, both theoretically and in practice. We have explored construction management and collaboration literature, and identified five possible directions for enriching current conceptions of collaboration within construction, in order

to build a model for supply chains. Four dimensions are shown in Figure 1; they are all underpinned by a fifth dimension, the fundamental proposition that collaboration has a competitive dimension.

2. TRENDS AND POSSIBLE DIRECTIONS IN THE CONSTRUCTION SUPPLY CHAIN LITERATURE

2.1 Nature of work: manufacturing production vs project based sector

One recurring debate in construction literature is whether supply chain principles and practices, originally grounded in production-centered manufacturing contexts, can be applied to construction settings, which are predominantly project-based. Bankvall et al. (2010, p. 396) suggest that supply chains are typically modeled around sequential interdependencies, whereas the construction industry is characterized by different types: pooled, reciprocal, as well as sequential (Thompson 1967), therefore making SCM application "problematic to use in the construction industry". As London (2005) highlighted, hybridization of the supply chain metaphor requires careful critique of the structural and behavioural characteristics of the 'real' supply chain. Therefore, we agree with Bankvall et al.'s (2010) characterization of the construction industry; however, we believe that this does not necessarily lead to the conclusions that supply chains have limited relevance in this sector. We propose that what is needed is a reconceptualising of supply chains so that the term "chain", which obscures certain dimensions of interdependence, can be rendered more flexible. We take up the argument of Harland (1996) and Christopher (1998), who proposed that supply chains could be better understood as networks. We propose further that these "supply chain networks" be analysed primarily as collaborative-competitive networks. Lehtiranta (2011, p. 141) has argued that "[i]n large and complex construction projects, relational risk is a major determinant of project success; collaborative work in project implementation has a potential for either significantly adding value or significantly withholding it". Characterizing these supply chains/ networks as collaborative will foreground the importance of the social (and not just technical) performance in settings of interdependence.

2.2 Nature of markets: supply chain structural and behavioral characteristics

It is also important to explore what researchers mean when they discuss who or what the "actors" in a supply chain are. Our review suggests that supply chains are often understood as interdependencies within or between organizations (Frohlich & Westbrook 2001; Nordin et al. 2010), although authors have also cited interdependence between organizational units as a prerequisite to achieving inter-organizational integration (Hale 1999). Inter- and intra-organizational perspectives on supply chains are important, but are understood to be underpinned by the "social network" approach, which focuses on structural features of internal and external networks, examining an organization's position within a network, and exploring the nature of influence from this position (Oliver & Ebers 1998). This approach tends to overlook other important dimensions of networks, a notable area being network "governance". In contrast to the social network perspective, the governance perspective "concentrates on attributes of both the networked actors and the form and content of their relationships within a particular institutional context" (Oliver & Ebers 1998, p. 569). London (2005; 2008) identified this through a conceptualization of the structural and behavioural market characteristics. These underlying characteristics give rise to the phenomenon of countervailing power between the actors in a supply chain, which ultimately is a characteristic of market competiveness which influences collaboration capacity (London 2008). These market characteristics are part of the so-called institutional dimensions of supply chains. Institutional dimensions of analysis include the "working rules" that govern patterns of human activity in a given domain: laws, court decisions, social norms and cultural conventions, religious doctrines, etc. (Kaufman 2007, p. 15). The role of institutions in discussions on supply chains has received scant attention since London's (2005; 2008) early work and this study shall build upon that earlier work but widen and deepen the institutional analysis. The previous work focused on the economic 'institutions' and did not consider government actors, professional associations, trade unions or any other wider external factors.

2.3 Nature of systems: interactions within the supply chain "ecology"

Having argued that supply chains involve institutional dimensions, we turn to the activity of supply chain management. Halldorsson et al. (2007, p. 286) argue that diversities in supply chain practices do not negate that "…all attempts refer to one specific 'setting', which is the management of relations of independent organizations in a particular structure." They go on to argue that "such management [is] the coordination and interaction of decision makers (i.e. *human beings*) from economic institutions within a system based on division of labor" (italics ours). Coordination and interaction, or what we refer to here as collaboration, is thus understood as a predominantly human activity. Empirical work on collaboration in construction seems to reflect this orientation. (see for example Shelbourn et al. 2007). This has led authors such as Ribes et al. (2013, p. 10) to conclude that collaborative work is still approached as a "fundamentally human endeavour". Noting this argument, we propose that the importance of non-human actors is a possible area for exploration in the field of supply chain collaboration, given that our interest is in the domain of construction where non-human actors (artefacts) are prevalent.

2.4 Nature of individuals: collaboration as a tool serving outcomes of performance

A final point to note has to do with the purpose of collaboration, in supply chains specifically as well as in management literature generally. In organizational studies literature, collaboration has been explored from a dominantly functional perspective, with much of the research emphasizing its purposes and its potential benefits (Hardy &Phillips 1998). Apart from being described as a mechanism for dealing with the complex problematiques that characterize present-day societies (Trist 1983), it has also been presented as a viable alternative to traditional conflict-resolution measures, as well as a strategy that addresses the environmental turbulence that arises when competitive organizations fail to cooperate in their actions (Gray 1985). Literature on strategy in particular has highlighted how collaborative efforts in various forms have enabled organizations to achieve firm goals and competitive advantage (Porter 1996) and to deal with uncertainty in the external environment (Gulati & Garguilo 1999). Many writers in construction management have echoed this tone, linking collaboration to widely-accepted measures of business success, for example efficiency, effectiveness, or profitability of a project (see Larson 1997), but others have argued that such traditional success criteria may be limiting, given that multiple external variables apart from partnering and collaborative activity may impact on project success (Dainty et al. 2003). We therefore agree trends that seek to move away from the use of traditional success indicators alone to assess the effects of various collaborative arrangements, and seek to explore its multifaceted outcomes (Hardy et al. 2005; Lehtiranta 2011; Shelbourn et al. 2007), one being its link to the creation of different types of "capital." It may also be useful to explore the "costs" of collaboration, including the (extreme) possibility that it can lead to business failure.

3. ACTOR NETWORK THEORY AS AN APPROACH TOWARDS DEVELOPING A COLLABORATIVE MODEL FOR SUPPLY CHAINS

We suggest that the directions defined in Figure 1 are the dimensions for a collaboration model for supply chains. We summarize (a) the research directions and (b) their corresponding dimensions in the proposed model in Table 1. We then suggest actor-network theory as an approach to developing this model through empirical studies. ANT is an umbrella term overarching theoretical, conceptual and methodological approaches built on the premise that much of reality is the effect of patterns of interaction between actors linked in heterogeneous networks (Law 1992). Methodologically, it upholds a number of assumptions, among them that human and non-human actors both have agency, and have equal ontological status (Law 1992); that "micro" level and "macro" level phenomena (a person or a nation) can be examined in the same way, by dismantling these into its actor components and examining interactions and that understanding what really makes up a network can only be achieved by following the actors We summarize how we plan to mobilize ANT in building the collaborative model in Column 3 of Table 1 below.

Table 1. Elements of a collaborative model and how an actor-network approach can support its development.

Current understandings of collaboration	Proposed dimension in collaborative model	How ANT can support the development of the model
Collaboration is understood as interactions between entities in sequential relationships	Collaboration is understood as interactions that reflect complex interdependencies: sequential, pooled, reciprocal	ANT assumes that much of reality is made of actors interacting in networks. Links between actors are not assumed a priori to be sequential. Links, and their collective configuration in a given setting like a construction project, are discerned by following the actors
Collaboration is understood as intra-organizational or inter-organizational.	Collaboration is understood from perspectives that can accommodate intra-organizational, inter-organizational, and institutional levels of analysis.	ANT takes the same approach to analysing phenomena at different levels. It is capable of "dismantling" networks whether they are intra-organizational or inter-organizational. It can also be mobilized at the organizational level.
Collaboration is understood as a dominantly human activity.	Collaboration is understood as an activity that includes human and non-human actors.	ANT upholds the assumption of "general symmetry", which means human and non-human actors both have agency and have equal ontological status.
Collaboration is understood from a functional perspective, mainly as a tool that leads to outcomes of performativity (efficiency, effectiveness, profitability).	Collaboration is understood to be linked, perhaps in a mutually constitutive relationship, with dimensions beyond performativity.	ANT is flexible yet agnostic. It foregrounds interactions (which may or may not be discerned to be collaborative) and the effects of interactions .

4. CONCLUSION

This paper lays the foundations of a theoretical framework to explore the nature of large scale offsite manufacturing efforts that require inordinate efforts of collaboration between actors. Collaboration in our study is viewed as a construct that is cognizant of the competitive nature of the housing sector and the various economic contractual procurement relationships that arise on projects. We are fundamentally interested in what interactions take place between actors (defined as both human and non-human) that give rise to seemingly successful large scale collaborative efforts. As we develop this collaborative model we are mindful that economic tensions arise

between project based chains and industrial market based 'chains' (or networks). The study seeks to conduct an in depth analysis of the nature of the key influencing actors towards establishing an ecological model that describes and assists prediction of the interactions between actors.

REFERENCES

Arif, M. and Egbu, C. (2010). "Making a case for offsite construction in China." *Engineering, Construction and Architectural Management,* 17 (6), 536–548.

Baiden, B.K., Price, A.D.F, and Dainty, A.R.J. (2005). "The extent of team integration within construction projects." *International Journal of Project Management,* 24(2006), 13-23.

Bankvall, L., Bygballe, L.E., and Jahre, A.D.M. (2010). "Interdependence in supply chains and projects in Construction." *Supply Chain Management: An International Journal,* 15(5), 385-393.

BEIIC, (2012) "Built environment industry innovation council." *Final Report to Government DIISRTE 12/230,*

Blismas, N., Pendlebury, M., Gibb, A., and Pasquire, C. (2005). "Constraints to the use of off-site production on construction projects." *Architectural Engineering and Design Management,* 1, 153 – 162.

Blismas, N., and Wakefield, R. (2009). "Drivers, constraints and the future of offsite manufacture in Australia." *Construction Innovation: Information, Process, Management,* 9(1), 72-83.

Blismas, N., Wakefield, R. and Hauser, B. (2009). "Concrete prefabricated housing via advances in systems technologies:Development of a technology roadmap." Engineering, Construction and Architectural *Management,* 17(1), 99-110.

Chandler, D. (2014). "A case for an Australian Construction Strategy," Commonwealth Government Productivity and Industry Discussion Paper http://constructionedge.com.au/?p=1290.

Chen, I.J. and Paulraj, A. (2004). "Towards a theory of supply chain management: the constructs and measurements." *Journal of Operations Management,* 22 (2004), 119–150.

Childerhouse, P. and Towill, D.R. (2011). "Arcs of supply chain integration." *International Journal of Production Research,* 49(24), 7441-7468.

Chinowsky, M. K. and Meredith, J. E. (2000). "Strategic management in construction." *Journal of Construction Engineering and Management,* 126(1), 1–9.

Christopher, M. (1998). *Logistics and supply chain management: Strategies for reducing cost and improving service,* Financial Times Pitman Publishing, London.

Dainty A. R. J., Cheng, M. and Moore, D.R. (2003) "Redefining performance measures for construction project managers: an empirical evaluation." *Construction Management and Economics,* 21(2), 209-218,

Fernie, S. and Tennant, S. (2013). "The non-adoption of supply chain management." *Construction Management and Economic,* 31(10), 1038-1058.

Frohlich, M. T. and Westbrook, R. (2001). "Arcs of integration: An international study of supply chain strategies." *Journal of Operations Management,* 19(2001), 185-200.

Gibb, A. (2001). "Standardisation and pre-assembly - distinguishing myth from reality using case study research." *Construction Management and Economics,* 19, 307–15.

Goodier, C. and Gibb,A. (2004). "Barriers and Opportunities for Off-Site Production." October pp. 75, DTI, ISBN 1 873844 57 3.

Gray, B. (1985). "Conditions facilitating interorganizational collaboration." *Human Relations,* 38(10), 911-936.

Groak, S. (1992). *The Idea of Building,* E & FN Spon Routledge, London.

Gulati, R. and Garguilo, M. (1999). "Where do interorganizational networks come from?" *American Journal of Sociology,* 104(5), 177-231.

Hale, B.J. (1999). "Logistics Perspectives for the New Millenium." *Journal of Business Logistics,* 20(2), 5-7.

Halldorsson, A., Kotzab, H., Mikkola, J.H. and Skjøtt-Larsen, T. (2007). "Complementary theories to supply chain management." *Supply Chain Management: An International Journal,* 12(4), 284-296.

Hampson, K. and Brandon, P. (2004) "Construction 2020: A vision for Australia's property and construction industry." Cooperative Research Centre for Construction Innovation for Icon.Net Pty Ltd. ISBN 0 975097725. Brisbane, Australia.

Hardy, C., Lawrence, T. B. & Grant, D. (2005). "Discourse and collaboration: The role of conversations and collective identity." *Academy of Management Review,* 30 (1). 58–77.

Hardy, C., Phillips, N. and Lawrence, T.B. (2003). "Resources, knowledge and influence: The organizational effects of interorganizational collaboration." *Journal of Management Studies,* 40(2), 321-347.

Harty, C 2008, 'Implementing innovation in construction: contexts, relative boundedness and actor- network theory', Construction Management and Economics, vol. 26, no. 10, pp. 1029-1041,

Hardy, C. and Phillips, N. (1998). "Strategies of engagement: Lessons from the critical examination of collaboration and conflict in an interorganizational domain." *Organization Science,* 9(2), 217-230.

Harland, C. (1996). "Supply chain management: Relationships, chains and networks." *British Journal of*

Management, 7, 63-80.
Housing Forum. (2002). "Homing in on Excellence: The use of OSM for UK house building industry." Housing Forum, London.
Kamar, K. A. M., Abd. Hamid, Z., Ghani, M. K., Egbu, C. and Arif, M. (2010). "Collaboration initiative on green construction and sustainability through Industrialized Buildings Systems (IBS) in the Malaysian construction industry." *International Journal of Sustainable Construction Engineering and Technology,* 1 (1), XX.
Kaufman, B.E. (2007). "The institutional economics of John R. Commons: Complement and substitute for neoclassical economic theory." *Socio-Economic Review,* 5, 3-45.
Khalfan, M., Maqsood, T., London, K. and Zhang, P. (2014). "Industrialised Building in the Housing Sector - Current State in Australia, Research Report 2." Prepared for Department of Industry by the Centre for Integrated Project Solutions, RMIT University, http://www.industrialisedbuilding.com/#!reports/c1s2zStahl, D. C.>(May 2014).
Krafcik, J. F. (1988). Triumph of the lean production system. *Sloan Management Review,* 30(1), 41-51.
Lamming, R. C. (1993). Beyond partnership - Strategies for innovation and lean supply. Prentice Hall, London.
Larson, E. (1997). "Partnering on construction projects: A study of the relationship between partnering activities and project success." *IEEE Transactions on Engineering Management,* 44(2), 188-195.
Latour, B. (2005). *Reassembling the social: An introduction to actor-network theory.* Oxford University Press, New York.
Law, J. (1992). "Notes on the theory of the actor-network: Ordering, strategy and heterogeneity." *Systems Practice,* 5, 379-393.
Lehtiranta, L. (2011). "Relational risk management in construction projects: Modeling the complexity." *Leadership and Management in Engineering,* April, 141-154.
London,K. (2008). *Construction Supply Chain Economics,* Routledge Taylor & Francis, UK.
London, K. and Siva, J. (2012). Accumulating intellectual capital for a novel innovative housing construction system in integrated supply chain environments, 7th Int. Conf.on Innovation in Architecture, Engineering & Construction , São Paulo, Brazil.
Loosemore, M., Dainty, A., & Lingard, H. (2003). *HRM in construction projects: Strategic & operational approaches.* Taylor &Francis.
Lounsbury, M. (2008). "Institutional rationality and practice variation: New directions in the institutional analysis of practice." *Accounting, Organizations and Society*, 33 (2008), 349–361.
Mandell, M. and Keast, R. (2007). "Evaluating network arrangements: Toward revised performance measures." Public Performance & Management Review, 30(4), 574-597.
Mentzer, J.T., DeWitt, W., Keebler, J.S., Min, S., Nix, N.N., Smith, C.D. and Zacharia, Z.G. (2001). "Defining supply chain management." *Journal of Business Logistics,* 22 (2), 1-24.
Nordin, F., Oberg, C., Kollberg, B. and Nord, T. (2009). "Building a new supply chain position: An exploratory study of companies in the timber housing industry." *Construction Management and Economics,* 28(Oct), 1071-1083.
Oliver, A.L. and Ebers, M. (1998). "Networking network studies: An analysis of the conceptual configurations in the study of inter-organizational relationships." *Organization Studies,* 19(4), 549-583.
Pan, W., Gibb, A. F. and Dainty, A. R. J. (2007). "Perspective of UK housebuilders on the use of offsite modern methods of construction." *Construction Management and Economics,* 25 (2). 183–194.
Pan, W. and Goodier, C. (2012) "House-building business models and off-site construction take-up." *Journal of Architectural Engineering,* 18 (2), 84–93.
PATH (2004). "Technology Roadmap: Advanced panelised construction." Prepared for U.S. Department of Housing & Urban Development, Office of Policy Development &Research, Washington, D.C, US.
Porter, M.E. (1996). "What is strategy?" *Harvard Business Review,* November-December, 61-78.
Ribes, R., Jackson, S., Geiger, S., Burton, M. and Finholt, T. (2013). "Artifacts that organize: Delegation in the distributed organization." *Information and Organization*, 23, 1–14.
Shelbourn, M., Bouchlaghem, N.M., Anumba C. and Carrillo P. (2007). "Planning and implementation of effective collaboration in construction projects." *Construction Innovation,* 7(4), 357-377.
Simatupang, T.M. and Sridharan, R. (2002). "The collaborative supply chain." *The International Journal of Logistics Management,* 13(1), 15-30.
Thompson, J.D. (1967). *Organizations in Action,* McGraw-Hill, New York.
Trist, E. (1983). "Referent organizations and the development of inter-organizational domains." *Human Relations,* 36 (3), 269-284.
Xue, X., Shen, Q. and Ren, Z. (2010). "Critical review of collaborative work in construction projects: Business environment and human behaviors." *Journal of Management in Engineering,* October, 196-208.