

RE-ENGINEERING THE CONSTRUCTION SUPPLY CHAIN: TRANSFERRING ON-SITE ACTIVITY, OFF-SITE

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Interest in supply chain management theory and practice in UK construction has grown considerably over the past decade. In parallel, a number of other key industry initiatives have also gained momentum. A notable development has been the increasing modularization of the construction process. The theoretical merits of off-site manufacture in construction are well documented and include reported benefits in production, scheduling and quality improvements. However, the impact of modularization on the governance and membership of the construction supply chain are less well-known. In an effort to connect supply chain management theory with modern methods of construction (MMC), the research investigates the potential impact transferring on-site activity, off-site will have on the supply chain. This is a conceptual paper based primarily on a review of supply chain management and MMC literature. Drawing on supply chain management theory and practice, the significance of an increasingly modular-orientated supply chain in construction is explored and evaluated. Secondary data is provided via anecdotal evidence gathered from a number of construction site visits and discussions with a cross-section of industry stakeholders. The adoption of modular construction and subsequent transfer of traditional on-site construction activities off-site is likely to necessitate a re-engineering of current construction supply chain management practice. In contrast to the commercially biased supply networks reflective of long-established working practices, off-site modular construction is likely to engender supply chain relationships that are increasingly socially as well as technologically bound and influenced by changes to the power dynamics. The literature highlights many business related opportunities, however the transfer of traditional construction activities upstream is not without risk. In conclusion, the research provides a conceptual grounding for further investigation of modular construction and the potential impact on the management and structure of construction supply chains.

Keywords: supply chain management, power, trust, relationships.

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INTRODUCTION

Transferring traditional on-site construction activity, off-site is both complex and potentially problematical. Many factors individually and collectively combine to impede the adoption of off-site modern methods of construction (MMC) including economic conditions, technological developments, historical influences and industry routine. Despite these challenges, increasing industry receptiveness for MMC continues to be largely motivated by the promise of productivity and performance improvements. The merits of off-site construction are well-documented (Goodier and Gibb, 2007) and may range from production benefits, programme benefits and manufacturing benefits (Doran and Giannakis, 2011). In contrast to the well documented productivity and performance benefits of contemporary construction processes, the scope and impact of MMC on the governance and membership of the construction supply chain are less well-known. This research seeks to explore the potential impact MMC and in particular modular construction will have on the governance and structure of traditional construction supply chains.

Supply chain management remains pivotal within arguments to improve the productivity and performance of organizations and continues to receive significant academic and industry attention (O'Brien *et al.* 2009, Pryke, 2009). Indeed, supply chain management has been drawn upon, connected with and frequently used as a lens with which to explore multiple research questions (Green *et al.* 2005). Within the context of the UK construction industry, aspirations of improved productivity and performance have been pursued for over sixty years (Murray and Langford, 2003). Supply chain management has previously been argued to be instrumental in delivering these aspirations (Egan, 1998, Egan, 2002). Notwithstanding repeated attempts to develop and diffuse concepts of supply chain management, construction, improvements in project productivity and organizational performance remain largely speculative. As a result, there still exists significant scope for supply chain development and improvement, especially when connected with parallel productivity initiatives, such as off-site manufacturing and MMC.

Off-site manufacturing and MMC are similarly argued to be instrumental in the delivery of productivity and performance benefits (Venables *et al.* 2004). Despite growing popularity for modularization of the construction process, off-site manufacture coupled with on-site assembly is not a new concept (Pan *et al.* 2008). Post Second World War construction was an enthusiastic sponsor of industrialized systems building and in particular prefabrication. Contrary to the initial optimism, serious product failures arguably left an indelible and consequently negative mark on the safety and build quality of industrialized systems (Green, 2011).

The ensuing lack of MMC investment and development has gone largely unchallenged over many decades, especially within the non-housing sectors. Despite increasing and compelling arguments in favour of MMC, industry implementation has been at best, circumspect. In an effort to connect supply chain management theory with MMC practice, this research investigates the potential impact transferring on-site activity, off-site will have on construction supply chains. Given the largely fanciful notions of construction project end-to-end service and product delivery, the focus of attention is primarily the supply side of the commercial dyad between the main construction contractor and second-tier construction sub-contractors and suppliers.

This paper is presented in a conventional format. Following a brief overview of MMC, a contextually sensitive interpretation of supply chain management in

construction is presented. The research strategy is explained and the research methods adopted are made clear. The findings and discussion section explore the largely theoretical debate concerning the commercial power and corporate leverage linked with the transfer of traditional on-site construction activities, off-site. The paper concludes with some reflections and identifies future research avenues.

MODERN METHODS OF CONSTRUCTION (MMC)

Reference to MMC was first coined by the newly elected Labour Government circa 1997. The prime driver for industry change was a political resolution to build low-cost affordable housing. The term, MMC in the main but not exclusively denotes the use of off-site systems of construction. Off-site prefabrication of building components ready for on-site assembly is an alternative approach to traditional on-site construction methods that will theoretically reduce the timescale for house building activities. In contrast to the political origins of MMC, the term has now been used in most sectors of the construction industry. Consequently, MMC is frequently used interchangeably with alternative expressions such as off-site construction, off-site manufacturing, prefabrication, industrialisation and modular construction.

Despite the growing popularity of MMC, a definitive definition remains elusive. In an effort to provide a greater degree of clarity, Ross *et al.* (2006) offer the following five classifications: 1/ off-site manufactured - volumetric, 2/ off-site manufactured - panellised, 3/ off-site manufactured - hybrid, 4/ off-site manufactured - sub-assemblies and components and 5/ non-off-site manufactured MMC. The five discrete categories of MMC identified by Ross *et al.* (2006) are worthy of individual analysis however this research will focus primarily on concepts of volumetric construction, commonly referred to as modular construction. According to Gibb (1999 p.8), modular construction may be described as "a unit, or units that form a whole building or part of a building in terms of full enclosure and structural needs". A typical example of modular construction would be a complete bathroom pod or plant room (Gibb, 2001).

Improving the productivity and performance of the construction process has been a recurrent topic of interest that has led to lively debate; this was evident by the publication of the UK government report 'Rethinking Construction' chaired by Sir John Egan. Egan (1998) championed the cause for greater integration of supply chains, component standardisation and off-site methods of construction. The report however, neglected the opportunity to endorse the increasing importance of alternative modes of supply chain governance with variant forms of off-site construction.

It is widely recognized that the UK construction industry remains largely traditional and conformist in its outlook. As a result of both history and routine, the diffusion of innovation and subsequent industry transformation to MMC may be difficult to alter. However, findings from a recent study by Nadim and Goulding (2010) suggest off-site methods of construction is likely to dominate construction technology for the foreseeable future. Notwithstanding growing awareness of the potential benefits, adoption of MMC is not automatically assured.

In a review of constraints likely to impede the uptake of modular forms of construction, Blismas *et al.* (2005) identify three discrete categories: namely, site constraints, process constraints and procurement constraints. First, site constraint refers to restricted or limited space available for facilitating the construction process, for example storage on a construction site. This category of constraint is largely reflective of city-centre or gap development where the building footprint occupies a

significant percentage of the total available land. Second, process constraints identify the limited capacity of suppliers. A shortage of available products from local suppliers may impact upon projected costs and reduce expected construction efficiencies. Third, procurement constraints relate to practitioner knowledge and understanding of novel methods of commercial exchange. Alternative procurement routes may be required to address anomalies associated with traditional forms of contract founded largely on pro-market, anti-trust approach to the construction process. It could be interpreted from the site, process and procurement constraints identified that management of the supply chain will have a considerable influence on the future uptake of modular forms of off-site construction. Central to the debate is greater integration between all stakeholders involved in modular construction both during manufacture and incorporation on site, thus forming longer-term and commercially enduring alliances.

POWER AND RELATIONSHIP MANAGEMENT APPROACHES

According to Cox and Ireland (2002), by understanding the resources that augment and diminish the relative power of both buyers and suppliers in specific exchange relationships, it is possible for practitioners to know what the objective circumstance is facing the parties in the relationship. This understanding provides buyers and suppliers the knowledge of the most appropriate relationship management approach available to them. The power matrix (Figure 1) could be used as a starting point to understand the objective position in the relationship. It is based on the premise that all buyer and supplier relationships are predicated on the relative utility and relative scarcity of the resources that are exchanged between the two parties (Cox *et al.* 2000).

Buyer Power Attributes Relative to Supplier	HIGH	BUYER DOMINANCE ($>$)	INTER- DEPENDENCE ($=$)
	LOW	INDEPENDENCE (0)	SUPPLIER DOMINANCE ($<$)
		LOW	HIGH
		Supplier Power Attributes Relative to Buyer	

Figure 1: The Power Matrix (Source: Cox *et al.* 2000).

The power perspective on buyer and supplier relationship management implies that the relative power of the buyer and supplier is the determining factor in the operational and commercial outcome in any transaction. This school of thought challenges the unquestioning use of collaborative approaches as it contradicts common-sense logic of economic theory. This logic asserts that the maintenance of perfectly competitive supply markets, with low barriers to entry, low switching costs

and limited information asymmetries ensures that suppliers innovate and pass value to buyers (Cox, 1999).

Given the fact that both buyers and suppliers are free to pursue symmetrical or asymmetrical relationship management styles with one another to achieve their respective business objectives reinforces the argument that there can be no single 'best practice' approach to relationship management (Cox and Ireland, 2006). In essence, integrated supply chain management, partnering, relationship marketing and the like may be regarded as a 'best practice' approach for organisations under certain circumstances but highly unlikely to be 'best practice' in all external sourcing situations. Therefore, practitioners have to first understand the way in which buyers can work with any supplier and the scope of their activities within a supply chain.

The discussion of power in buyer-supplier relationships provides a useful starting point prior to considering the power structures within the entire supply chain. In the construction industry, the dyad between the client and the main contractor is also affected by the relationship that the main contractor has with its subcontractor and suppliers. There is a need for understanding the extended network of dyadic power relationships in order for appropriate relationship management strategies to be developed and is referred to as the 'power regime' (Cox *et al.* 2000, Cox and Ireland, 2006). Only by understanding the structure of power within the network as a whole is it possible to understand the feasibility and desirability of introducing reactive arm's length or proactive collaborative relationship strategies for the buyer and supplier.

Another issue that needs to be questioned is the notion where both parties fully achieve their ideal goals and referred to as a 'win-win'. This ideal is not feasible in practice because of the incommensurability of the objective commercial interests of both parties. This is the central paradox of all relationship management approaches between buyers and suppliers (Cox, 2004). This implies that it possible for buyers and suppliers to achieve operationally and commercially all or something of what they value ideally but difficult for both parties to do so simultaneously. There are three 'mutuality' outcomes in which long-term collaboration relationships between buyers and suppliers are sustainable. These are win for the buyer/partial win for the supplier; partial win for both the buyer and supplier; and win for the supplier and partial win for the buyer.

Although neither party would wish to operate in a 'lose-lose' arrangement, one-off business relationships do not require the maintenance of a relationship so a 'lose' outcome is not an issue for the winner. The implication of this is that the promotion of a widespread use of collaborative approaches may not be desirable or sensible. If there is no necessity for operational continuity then opportunism may be more beneficial for one party than to pursue the collaboration. This may explain the traditional common occurrence of the main contractor behaving opportunistically in dealings with subcontractors because of their wide availability due to low barriers to entry.

RESEARCH STRATEGY

This is a conceptual paper. The research strategy is not to hypothesize and test a theory but to explore the opportunities and challenges connected with a modularization of the supply chain and the transfer of traditional on-site construction activity, off-site. Whilst it is acknowledged that the construction industry is both diverse and complex, a number of research parameters have been introduced. The primary focus of attention is the organizational interface between the main

construction contractors and their second tier construction sub-contractors and/or suppliers. In addition, the potential influence and subsequent impact of other construction stakeholders, for example the construction client is acknowledged and where appropriate commentary is provided. The research is not without limitations and assumption. Notable exclusions from the discussion are construction activity outside the UK, house building and builders merchants.

Research Method

The research method relies primarily on a literature review. Drawing specifically on supply chain management theory and practice and examples of off-site manufacture, the significance of an increasingly modular-orientated supply chain in construction is explored and evaluated. Secondary data is provided via anecdotal evidence gathered from a number of construction site visits and discussions with a cross-section of industry stakeholders. These include discussions with senior construction managers from first tier construction contractors and second tier construction sub-contractors and/or suppliers.

DISCUSSION

The economic exchange of construction services and products does not occur in a vacuum. Consequently, many factors impact individually and collectively on the commercial decision-making process. The discussion that follows draws particular attention to two key factors. First, the organizational interface between the main construction contractor and construction suppliers specializing in the provision of construction technologies collectively labelled as modern methods of construction (MMC). Second, the re-engineering of the construction supply chain and associated positions of power and trust.

Organizational Interface

The theoretical merits of off-site manufacture and MMC are well documented (Doran and Giannakis, 2011). Over the past decade construction clients have been seen as the main protagonists for MMC. However, it could be argued that main construction contractors also have a notable role to play. The adoption or rejection of MMC for main construction contractors is a choice among alternatives, inextricably linked with wider business interests, project objectives, commercial risk and management of uncertainty. Consequently when afforded the choice between traditional on-site operations or increasing implementation of off-site MMC, the non-adoption of MMC may be an instrumentally rational response to managing power and anti-trust relations.

Consequently, construction industry adoption of MMC is not a decision based solely on technological capacity and capability. On the contrary, central to industry adoption and utilization of MMC is the management of the organizational interface between the client, main contractor and the MMC supplier. Given the power and relationship management approaches outlined by Cox *et al.* (2000), a shift towards a manufactured product base would arguably alter the traditional relational dynamics of the construction supply chain. Introducing ever-increasing technological specialization and standardization in to the manufacturing and supply network arguably limits the choice of capable suppliers available to the main contractor. The rise in prominence of highly 'specialist' sub-contractors offering products and services that are both beneficial and simultaneously scarce generates a commercial power shift within the supply dyad that construction main contractors may find unnerving and clients, problematic.

Given industry experience of endemic insolvency (Chevin, 2010), main construction contractors and clients are justifiably cautious. Recent research suggests one in ten large construction organizations are dependent upon high-risk suppliers (CIOB, 2012), a disquieting trend that raises growing questions of supply chain insecurity and exposure to commercial risk. A recent site visit to a major NHS hospital development confirmed this concern. The senior project manager was keen to explain that if a plumbing organization went in to liquidation, they could be replaced with minimum disruption. On the contrary, if a specialist supplier of bathroom pods went in to liquidation, then operational consequences for the project in terms of cost, time and specification would be substantial. Given the choice, main contractors may take a business-orientated decision to negate the opportunity to promote MMC in favour of well-established, low-risk and readily available construction trades.

In terms of supply chain governance, the lower the technical development and specialization, the lower the risk and commercial commitment of the main contractor. Conversely, the higher the technical development and specialization associated with the product or service (for example bathroom pods), the greater the commercial interdependency. Managing varying degrees of service or product specialization is arguably a central concern when adopting MMC. For some, recognition of increasing levels of specialization and project standardization requires resourceful management and a potential re-engineering of the construction supply chain governance structure.

Re-engineering the Construction Supply Chain

The notion of re-engineering the construction supply chain is not intended as a panacea for poor construction productivity and performance. The construction industry, like many other sectors is capable of supporting alternative forms of commercial exchange (Miles and Snow, 1986). However, MMC complete with ever-increasing levels of technological innovation and complexity arguably necessitates relational management and organizational integration some may consider atypical of the construction sector.

An alternative to traditional, arm's length contracting is a hybrid mode of governance. Neither a market nor hierarchy, a hybrid mode of governance (network or clan) reflects risk-sharing both parties willingly undertake and governance mechanisms put in place to resolve inherent contractual imprecision. In short, "trust supplants power as the key concept" (Williamson, 2008 p.10). For example, if considerable project risk resides with the supplier of specialist modular units then the unit cost to the construction contractor and the client will be greater than if the risk resided primarily with the construction contractor. Conversely, if the risk is absorbed by the construction contractor the unit cost would arguably come down but at the potential expense of commercial power and leverage. The balance of the commercial exchange however may be countered if the construction contractor can incentivise longer-term relations via guarantees of regular demand and volume. Given the trading challenges facing the supply-side of the MMC market, the specialist supplier would find it difficult to sever commercial ties with the buyer (Cox *et al.* 2006). The resultant collegiality of the commercial exchange alleviates the inherent risk associated with MMC and may provide a cost effective way to pilot innovative construction methods.

Building on Cox *et al.*'s (2000) power regimes and Williamson's (1975) concept of transactional cost economics (TCE), the technology of transacting (Williamson, 1996) and interpretation of supply chain management (Williamson, 2008); a correlation between varying degrees of MMC development and specialization and alternative

supply chain governance structures may be projected (Figure 2). If technical development and specialization (s) is negligible ($s = 0$), a buy option via pro-market governance of the supply chain may provide the optimum performance outcome. Due to the homogeneous nature and ample availability of the commodity there is very little commercial incentive to cultivate long-term relationships (Gruneberg and Ive, 2000). Alternatively, if technical development and specialization is very high ($s = 1$), a make option via an organizational hierarchy may provide the optimum solution given that substantial levels of specialized investment are difficult to support via a market mode of governance (Zenger and Hesterly, 1997). If technical development and specialisation is neither zero nor one ($0 < s < 1$) then a hybrid mode of governance either a supply network or clan may provide the commercial agility and relational flexibility (Powell, 1990, Ouchi, 1980) to accommodate varying degrees of specialization and product standardization frequently associated with MMC.

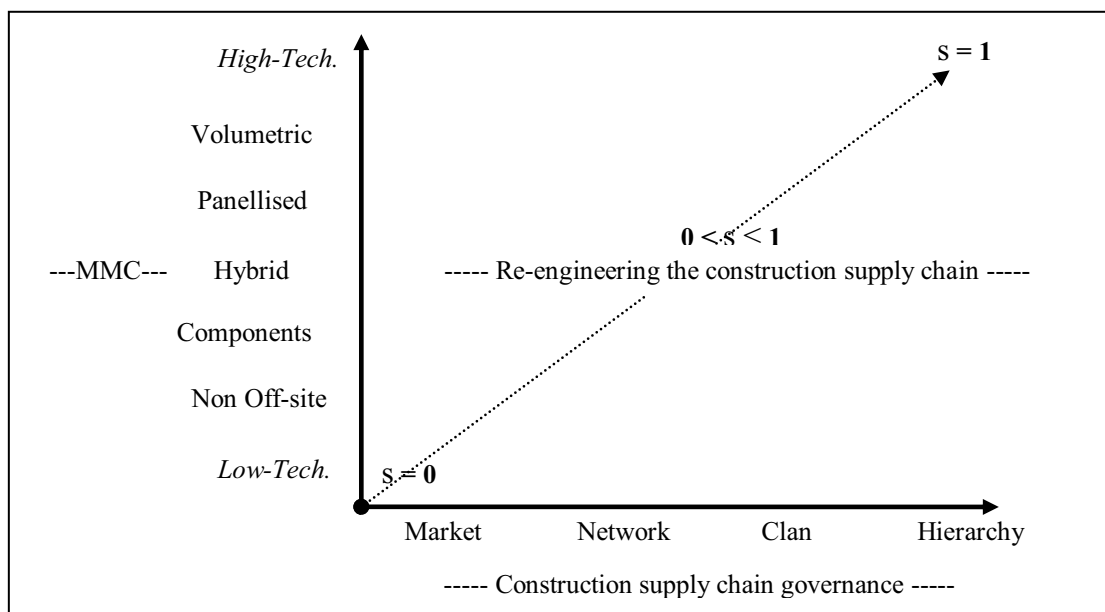


Figure 2: Re-engineering the construction supply chain

In contrast to much of the prevailing literature, the promotion and implementation of MMC needs to be explored from research perspectives other than technological. Developing a research agenda drawing on multiple theories of innovation, diffusion and organizational institutionalism is likely to portray an insightful and alternative prescription of MMC and industry interest regarding transferring on-site activity, off-site. Construction innovation, diffusion and organizational institutionalism and by extension mechanisms of institutional change are inextricably linked (Redmond, 2003). Given that you cannot have one without the other(s), re-engineering supply chain management practice rooted in the institutional assumptions of pro-market trading and by extension supply chain governance, is likely to prove difficult.

CONCLUSIONS

The imminent challenge for MMC is not primarily technological. On the contrary, the technological capability and capacity for modular construction is both advanced and viable. The challenge for MMC is trust. Construction management inability or intransigence to re-engineer the supply chain governance structure to accommodate commercial relations that are increasingly economically, socially as well as

technologically bound may ultimately impede the adoption and subsequent implementation of MMC.

The constant interplay between power and trust in the majority of construction transactions provoke both parties to remain guarded of the commercial motives driving the relationship. There arguably exists a Pareto optimal, where the rewards of the buyer cannot be increased without reducing the rewards of the supplier and vice versa. Given the prerequisite for equilibrium within the economic transaction of construction goods and services, supply chain relationships governed by trust remain largely fanciful. Repeated failure to supplant power with trust may have far-reaching consequences for a construction industry keen to exploit the productivity and performance benefits of MMC.

In the absence of trust, provisional lessons from the construction industry (Buildoffsite, 2009) suggest a 'make' option via a hierarchical organizational structure may provide the optimum governance solution to the design and off-site manufacture associated with MMC. However, a hierarchical form of supply chain governance replacing price and trust with authority and competition and collaboration with bureaucracy is not without limits. Consequently, the implications and limitations of alternative modes of supply chain governance (market, network, clan and hierarchy) and MMC need to be studied and better understood from multiple perspectives including innovation, diffusion and institutional change. Otherwise, non-adoption of MMC may provide a persuasive and 'risk-adverse' solution.

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