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Procurement Routes, Supply Chain Management and Building Information Modelling: A Review of Trends and Impacts on the Construction Industry

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Abstract

It has been argued that the construction industry is distinct from other industries and must therefore find solutions that align with its peculiarities. Over the last three decades, several reports, primarily Latham (1994) and Egan (1998) have spotlighted systemic issues underlying the construction industry. The construction industry is highly fragmented evidenced by a high level of subcontracting and a lack of integration within supply chains. Poor information management has also been a common thread on most construction projects. The adversarial culture of project stakeholders and low productivity has been repeatedly discussed in the literature. Particularly, in the 1990's discussions on poor information management, loosely coupled supply chains, and lack of collaboration took center stage. Addressing these issues, given the transformational changes in other industries, has resulted in the drive by the construction industry to proffer alternative methods of procurement and supply chain management centered on Building Information Modelling. This report compares the advantages and disadvantages of the different procurement methods available to construction projects, examines the impact of Building Information Modelling on procurement methods, and also outlines the trends in digitalisation within the built environment and its implications for procurement.

Keywords: Building information modelling, construction, digitalization, procurement, supply chain

INTRODUCTION

Procurement, within the context of the construction industry, can be defined as the method based on which external resources needed for the completion of a project are obtained and organized (Davis, et al 2008). It also refers to the organizational structure adopted by the client for the management of a building project from design to construction (Masterman, 2002). Other definitions of procurement methods extend it to the financing operation and facilities management of a project (Love et al., 1998, Luu et al., 2003). From this perspective, various procurement systems or methods abound. These range from the earliest traditional method, design, and build method as well as management methods - Construction management/management contracting to other innovative methods (Masterman, 2002; Davis, et al 2008). Other procurement routes include the Design-Build-Operate (DBO) and Design-Build-Finance-Operate (DBFO) (Mathonsi and Thwala, 2012). Other mechanisms of procurement such as partnering, Public Private Partnership (PPP), and Private Finance Initiative (PFI) are also in use. More contemporary procurement methods such as collaborative working procurement and alliancing are now becoming commonplace, partly aroused by the team-focused rethinking construction drive propagated by Latham (1994) within the UK. Although Latham (1994) is widely acknowledged to have initiated the

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construction industry reform towards adopting supply chain management, counterarguments such as Davis (1995) as well as Cox and Townsend (1997) are of the view that the report was mostly a compilation of viewpoints, around which a consensus had to be taken. Yet, the Egan report (1998) re-emphasized Latham's (1994) position on the need for integrated processes and teams. Egan (1998, pp. 4) reiterated the need for integrated project processes centered around four key themes: '*product development, project implementation, partnering the supply chain and production of components'.* Ferni and Thorpe (2007) however questioned the universality of the client's worldview presented. Irrespective of the varying stances evident in the literature, drivers of change such as BIM and other digitally-led innovations have strived for closer working relationships within the supply chain and led to a wider proliferation of procurement methods (Luu et al., 2003).

PROCUREMENT METHODS: ADVANTAGES AND DISADVANTAGES

As the Latham Report (1994) espouses, the decision on what procurement route to adopt must be guided by the nature of the project and the client's acceptance of risk. The Latham report (1994) further outlined that project objectives such as early completion, price certainty, risk avoidance, etc. will determine which procurement methods are suitable. The traditional method of procurement is also referred to as the Design-Bid-Build method. The design and construction process are kept distinct i.e. consultants are appointed for design as well as for cost control, while the contractor is primarily responsible for executing the work (Davis et al., 2008). The design and build procurement method offers a procedure where a single contracting organisation is solely responsible for the design and the construction under a single Design-Build lump sum contract, following standards dictated by the client (Koppinen and Lahdenperä, 2004). For management-oriented procurement methods, an organisation is responsible for the management of the project, interfacing with the designer as well as other consultants (Sawalhi and Agha, 2017). The management also oversees the physical operations that are executed by the contractors (Mathonsi and Thwala, 2012).

The traditional procurement route accounts for the fragmentation of construction projects, whereby on simple projects, main contractors and design consultants serve as separate tier-1 suppliers (Davis, 2008). With increasing project complexity, numerous suppliers may be engaged, which may then generate an extended network of contractually disconnected supply chains. From a supply chain perspective, therefore, the shortcomings of the traditional method primarily hinge on the non-integrated nature of the supply chain, lack of early collaboration, and adversarial culture (Natasa and Car-Pušić, 2008). Egan (1998) resounded the need to replace traditional procurement, with contracts that seek the best overall value within the supply chain, which are not just based on minimum price. The traditional method of procurement however remains in use to date, despite calls for client-led change from competitive pricing in favour of more collaborative procurement methods rooted in long-term relationships (Egan, 1998). This may be attributed to the advantages of the traditional procurement method such as accountability/transparency of the competitive process which lowers the contract price, and the price certainty upon contract award (Noaum, 1994). Typically, the traditional method was used in the Research primary school case study led by Kennedy Nolan Architects, worth $5.7 million (Davis et al., 2008).

Unlike the traditional method, the Design and Build procurement method provides the advantage of a single point of responsibility with less client risk (Masterman, 2002). It is asserted that the design and build procurement route enables better integration within the supply chain network, with less adversarial relationship (Natasa and Car-Pusic, 2008). This is because it creates a platform for a fully integrated team to work together from the project onset. This was typical in the case of the A4232 Eastern Bay Link Cardiff, UK, whereby the team worked closely to overcome initial difficulties in preliminary designs. The design-build method also provides a framework for early project completion, due to the overlap between design and construction (Mathonsi and Thwala, 2012). It may however pose disadvantages due to the difficulties in comparing alternative design offers, and loss of control over

design (Masterman, 2002). Costs may also be higher, as fully competitive bidding is limited compared to the traditional method (Sawalhi and Agha, 2017).

Procurement methods such as construction management, management contracting, and 'design and manage' are all variants of the management procurement method (Davis et al. 2008). There are a number of advantages to the management method of contracting, such as having a unified point for addressing client issues, competitive letting of work packages, flexibility for design changes, and the potential for overall cost/time savings (Sawalhi and Agha, 2017). Typically, the Sidney Myer music bowl, in Melbourne which underwent significant restoration, adopted the construction management procurement method and benefited from its flexibility in supporting requisite design changes and adjustments (Mathonsi and Thwala, 2012). On the other hand, a key disadvantage of management procurement methods includes higher client risk due to multiple coordination points within the supply chain. Figure 1 is an extract showing common areas of concern/conflicts in the management procurement supply chain, based on the outcome of an empirical study of a large London-based case study.

- *Concerns over the clarity of the requirements of trade contractors within a work package and between work packages.*
- *The level of 'unlearning' of traditional subcontractor behaviour to accommodate a new autonomous status by trade contractors.*
- *The uncertainty about the role to be played by trade contractors' site managers in respect of the construction managers.*
- *The uncertainty of the trade contractors about their influence over project decisions.*
- *The uncertainty about the level of input from the client.*

Figure 1. Common Areas of Concern/Conflicts (Dodd and Langford,1990).

Therefore, although management procurement methods foster collaboration between the client and the management contractor, Dodd and Langford (1990) outcome indicates that inadequate supply chain integration between the tier-1 and tier-2 layers may constitute a disadvantage. The numerous subcontracts, further pose difficulty in programming work, and price certainty can only be attained when the final work package is subcontracted (Lahdenperä, 2008).

The emergence of collaborative working procurement methods such as frameworks and strategic partnering reaffirms the move towards supply chain integration. They are however better suited for larger clients with continuous or repetitive workloads. Forms of collaborative working procurement have been adopted by the National Change Agent (NCA) - housing programme, Lincolnshire's Local Authorities, and the Midlands Highway Alliance (Constructing Excellence, 2009). Collaborative procurement has advantages such as cost savings from not having to rebid and form new teams for each project, improved performance/buildability as a result of learning from previous projects, and the integrated nature/maturity of the supply chain. These benefits were evident in London Borough of Hackney and Hackney Homes, which achieved 10% and 35% savings in tendered rates for phases 1 and 2 of its Decent Homes project, through working with strategic alliance partners and supply chain (*Constructing Excellence*, 2009). Collaborative procurement may however have the disadvantage of losing market value due to the repetitiveness of the tendering arrangement.

Impact of Building Information Modelling (BIM) on Procurement Methods

BIM is a computer-generated model of a project which facilitates information sharing in a digital format among project stakeholders and professionals, thereby enhancing the collective comprehension of design intent as well as promoting supply chain and life cycle integration (Azhar et al., 2008). The advent of BIM has been advantageous for other procurement functions such as tendering processes, resource planning, and scheduling (Azhar et al., 2008; Chevin, 2017). Several

case studies attest to the benefits of BIM. Case Studies of BIM in use were demonstrated in Precast Concrete Design by four Structural Engineering Firms that experienced an improvement in engineering design quality and labour productivity (Olofsson et al, 2008). Another case study of a large healthcare project showed the benefits of complete pre-fabrication in plumbing works, less than 0.2% rework, zero design conflicts, six months' time savings, and a $9M savings in overall project cost (Olofsson et al, 2008).

A common misconception about BIM is that it is an ICT tool only. Yet the most copious impact of BIM on procurement is its ability to foster collaboration. BIM is particularly important in complex projects as it facilitates multidisciplinary collaboration (Both, 2012). BIM has thus triggered a shift in paradigm from conventional procurement philosophy, which is characterized by fragmentation, to integrated service delivery and co-ownership of virtual properties (Gibbs et al., 2012). Standard forms contracts such as the JCT 2011, NEC 3, and PPC 2000 have various treatments of BIM in contract terms that provide for an early contractor, subcontractor, and supplier involvement (Ilozor and Kelly, 2012). The scope of services offered on BIM-enabled contracts now includes other roles such as the BIM coordinator. Furthermore, the BIM protocol can be incorporated as an amendment in professional service engagement.

A range of innovative procurement methods is now available, with the intent of fostering collaborative procurement (Lahdenperä, 2012.). These include new procurement methods such as Project Alliancing/Alliance Contracting (PA); Integrated Project Delivery (IPD) and Early BIM Partnering. These procurement methods rely on BIM as a core component of the design, construction, and asset management of projects (Hampson and Kraatz, 2013). Typically, the Project Alliancing and Integrated Project Delivery methods are based on 'multi-party' contracting between the project players, with all parties forming a joint organization to assume joint responsibility for both the design and construction as well as risk-sharing (Petajaniemi and Lahdenpera, 2012). This facilitates the formation of collaborative teams and the early contribution of expertise and knowledge (Table 1).

Table 1. BIM Enabling Collaborative Features on PA and IPD.

	BIM Enabling collaborative features
Integrated Project Delivery (IPD)	• Integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants through all phases of design, fabrication and construction' • Teams usually include many experts and not only owner, designer and contractor who enter into a single collaborative contract, a multi-party agreement to share risk and potential rewards. • Promotes a tight collaboration between all the parties involved from early design through project handover • The client and/or a consultant need to be part of the integrated team to help the management of the process
Project Alliancing (PA)	• based on a 'multi-party' contract between the players involved in a project • parties assume joint responsibility for the design • construction to be implemented through a 'joint organisation', which incorporates the client • players share both positive and negative risks- observe principles of openness and information accessibility to promote collaboration and 'no fault, no blame culture • different parties consider other's views and cooperate more efficiently

(Bolpagni, 2013)

Whilst these aforementioned procurement methods lend themselves to BIM incorporation because of their collaborative nature, the Early BIM partnering method, is specifically tailored to utilize BIM on public projects (Figure 2).

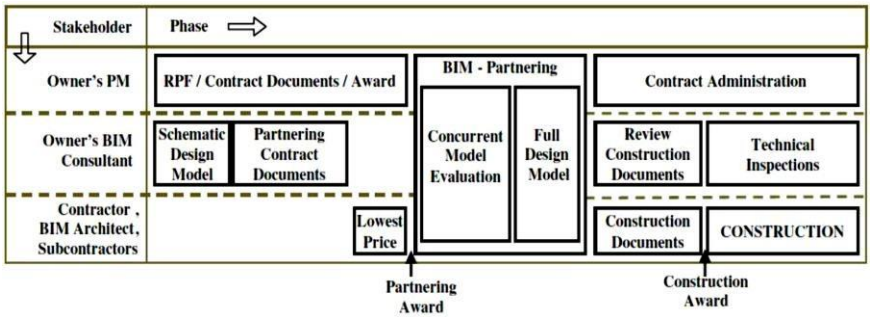

Figure 2. Early BIM Partnering, (Bolpagni, 2013).

BIM has been benchmarked as a primary platform for procurement in many developed countries. In the UK, level-2 BIM has been made mandatory on all public projects, whereby all parties to the construction can access and make contributions to a single BIM model. Cost Led Procurement, Two-Stage Open Book, and Integrated Project Insurance are the three BIM-based procurement methods developed in the UK (Bolpagni, 2013). Trial projects such as the Cookham wood and the North Prison case studies attest to the cost, time, and collaborative benefits of the two-Stage Open Book procurement method of BIM incorporation in the UK. In support of these new procurement approaches, several industry frameworks have been established in the UK, such as the PAS 1192:2 and PAS 1192:3 frameworks, to address the BIM information requirements of different stakeholders throughout the building life cycle (Philp, 2012).

Digitalization Trends in the Built Environment: Impact on Procurement Methods

Evolving information and communication technologies have caused a shift from conventional methods of working and triggered change and modernization in the built environment. Digital technologies such as 3D printing, Internet of Things (IoT), Augmented and Virtual Reality, etc. have permeated every aspect of construction. According to Froese (2010), the trend in digitalization specific to construction procurement activities can be delineated into three phases (Figure 3).

- the deployment of Computer Aided Design (CAD) system to carryout and support processes in 2D architectural design, cost estimating and structural analysis, whereby outputs and mode of information sharing were still mostly paper-based.
- the use of non-paper-based technologies -e-mail and web-based and other computer-assisted communication technologies/tools as well as document management system.
- the move towards integration and collaboration-based technologies, such as BIM, web-enabled project management software and cloud computing.

Figure 3. Phases of Digitalization.

This trend indicates a shift in paradigm in digital technology uptake from supportive CAD-based applications to integration and collaboration enabling data management systems. Typically, Whyte and Lobo (2010) study of a public-private partnership (PPP) project in a European motorway, revealed that several types of digital technologies (3D printing, Internet of Things, and Geographic Information Systems) were deployed in the design and engineering of the work by the different stakeholders to facilitate communication, coordination, and knowledge sharing. Particularly, the adoption of BIM enabled the easy exchange of project data, enabled collaboration in real-time, and facilitated the virtual construction of the facility before its actual physical construction. This minimized uncertainty and helped in simulating and working out potential problems. Furthermore, sub-contractors from the different trades were able to collaborate and share critical information, which was imputed into the

model before construction began. Opportunities for pre-fabrication and offsite pre-assembly were noted and utilized.

Different digital technologies applied to different aspects of procurement can be identified. In the appointment of consultants and professional team Web-based applications are utilized. In the preparation of procurement documents, CAD and BIM-based applications are used for design, engineering as well as for quantity take-off. Advanced CAD-based technology includes Autodesk Revit, Bentley Architecture, and Graphisoft ArchiCAD. Other digital technologies utilized include Vico Constructor Tekla Structures and Autodesk Naviswork. Digitalization also supports visualization and virtual reality in procurement via Interactive, 3D computer applications. In establishing a procurement strategy and management of supply chains, Web-based Enterprise Resource Planning (ERP) is used to integrate functional and departmental information flow within organizations into single computer systems (Alpers et al., 2014). Web-based Project Portals are used in tender solicitation as a basis to gather information about different organizations, their services, and products. Online transactions and information exchange such as the transmission of drawings are also facilitated (Sheng et al 2020). Cloud computing technology and specifically tailored internet-based applications (Software-as-Service) such as 'Decision Max' serves as a basis for e-Tendering. Video conferencing and multimedia technology are also utilized to clarify bid information during tender evaluation and also during contract award (Amarapathy et al., 2013). During contract administration, LADAR (laser distance and ranging) technology or a 3D scanner is used with photogrammetry to rapidly track changes in the quantities of work carried out on sites. Radio Frequency Identification (RFID) technology is deployed in the tracking of project materials down the supply chain. Live images of project sites can be captured directly into the project team computers via the use of Web-based cameras, thus facilitating remote project monitoring. Other digital technologies applied to procurement include Bar Code technology, electronic data interchange (EDI), and e-market places. The emerging trend in digital technologies now includes blockchain and smart contracts (Abdel-Basset et al., 2018; Ali et al 2018)

Profound and continuing changes have correspondingly occurred in digitally enabled procurement models (Whyte, 2019). The pace of innovation in digital technology means that project deliverables are changing from just physical products to include digital information as the physical and digital interact. This has evolved supply chains and redefined relationships with operators, clients, and end-users. Digital workflows rather than paper-based documentation, are becoming increasingly central to public project procurement methods (Table 2).

Table 2. Digitally Enabled Project Delivery Trends in Mega Infrastructure Projects.

	Project Delivery Models	**Digitally Enabled Delivery**
Heathrow Terminal 5	Long-term owner-operator BAA acted as the delivery client for the project and used the T5 Agreement to share risks and rewards.	Single model environment, held by BAA with access for first-tier suppliers, used to coordinate and manage interdependencies across subprojects. The design software was provided by Autodesk through a reseller.
London 2012 Olympics	The megaproject delivery client, the Olympic Delivery Authority (ODA), worked with a delivery partner, CLM. Contracts for the major venues used a collaborative contract, New Engineering Contract (NEC) 3, option C (a target contract with activity schedule).	Contracts were out before the digital strategy was developed, and so different subprojects used different technologies, and then files were converted for archiving and for hand-over by CLM and passed to ODA for onward transmission to games in 2012 and long-term owners and operators.
Crossrail	Crossrail acts both as the megaproject delivery client and delivery partner. The three major tunneling contracts used a collaborative contract (NEC3, option (C). Different parts of the line will have	A central information strategy was put in place, with GIS, BIM, and asset management data being aggregated and stored at project level. There is a strong partnership with Bentley Systems: All contractor were trained in use of

	different long-term owners and operators, with hand-overs to Transport for London and Rail for London.	data, and the quality of information they developed was monitored.
High Speed 2	HS2 is the megaproject delivery client, with CH2 M, Atkins, and SENER as delivery partner in Phase 1, with contracts in Phase 1 using a collaborative contract (NEC3, option C).	The ambition is to receive information in standard formats rather than to specify data, and to use standard processes. There is a BIM roadmap associated with the project.

(Whyte, 2019)

The widespread deployment of digital information and technology has thus transformed the conventional procurement methods frontier (Lobo and Whyte, 2017). Conventional procurement routes still exist but are now becoming heavily shaped by digital integrative strategies. Digitalisation has redefined the relationships between the project team, created new norms for approvals and workflow monitoring, and has resulted in new forms of professional accountability. (Jaradat et al., 2013; McKinsey, 2014).

CONCLUSION

Procurement methods have undergone transformational modifications, triggered primarily by paradigm shifts in supply chain management, the development of Building Information Modelling, and other forms of digital technologies. Despite counter-arguments surrounding the contextual applicability of supply chain management principles in the procurement of construction projects, BIM and digitalization provide a pathway to change in technical operations which links directly to promoting partnering and collaborative practices recommended by Latham and Egan. The overarching theme of BIM and technology triggered change center on process change from fragmentation to integration within procurement methods. In this age of digitalization, therefore, the adoption of BIM-enabled procurement methods has become a panacea for survival in the construction industry. Particularly the need for wider adoption of BIM becomes critical, in view of the accelerated changes caused by the Covid-19 crisis. This report, therefore, makes a case for promoting collaborative relationships, particularly hinged on the adoption of BIM and digital technologies.

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