Enhancing Off-site Manufacturing through Early-Contractor Involvement (ECI)

Author 1

- David Finnie,
- MConst (Construction Law) with distinction, BConst (QS), GCTLT, Dip QS, MNZIQS, MNZIOB, Chartered Building Professional, LBP (Site 2 & Carp),
- Senior Lecturer in Built Environment School of Architecture, Building and Engineering, Otago Polytechnic, Dunedin, New Zealand

Author 2

- Dr. Naseem Ameer Ali,
- PhD Civil Engr (Univ of Auckland), MSc Const Law & Arb (Kings College London), MSc Arch: Building Econs & Mgt (University College London), BSc (Hons) QS (Reading), CDipAF, Cert Adj (RICS), Cert Adj (KLRCA), PPRISM, FRISM, FCIOB, FCIArb, MNZIQS, MRICS, MAPM, AIQS (Affil), Reg QS (NZ), Reg QS (M'sia), Chartered Quantity Surveyor (UK), Registered Quantity Surveyor (NZ & M'sia), Chartered Construction Manager (UK), Accredited Mediator (CIDB, M'sia), Panel Adjudicator (KLRCA & RICS),
- Senior Lecturer in Quantity Surveying School of Engineering and Advanced Technology, Massey University, New Zealand
- ORCID number

Author 3

- Dr. Kenneth Park,
- PhD, MSc, BSc, FHEA, MCIOB, MRICS, CCM, PMP,
- Senior Lecturer in Construction, School of Engineering and Applied Science, Aston University, UK
- ORCID number: orcid.org/0000-0002-8406-3847

Full contact details of corresponding author.

Email: David.finnie@op.ac.nz

Phone: +64 3 479 6096 Ext 8096

Mobile: +64 21 396 1111

L Block Anzac Ave, Private Bag 1910, Dunedin 9054, New Zealand

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Abstract (150 words)

Procurement strategies that enable early contractor involvement (ECI) in design may enhance off-site manufacturing (OSM) by overcoming previously identified barriers to its uptake. Involving constructors during the design stage can reduce the risk of design buildability issues and standardizing traditionally bespoke ECI processes may help overcome cultural resistance to unfamiliar OSM technology. Following literature review and using case studies, document analysis, and legal doctrine, a two-stage ECI conceptual process model for New Zealand was proposed. This was tested and refined following feedback at a conference. The model comprises a first-stage pre-construction contract and a second-stage standard form construction contract. Key process variables are considered with solutions to provide collaboration and transparency while maintaining competitive fixed pricing across the supply chain. Legal doctrine analysis is used to distinguish between design buildability obligations and design codes compliance. The model contributes towards the development of standard form pre-construction contracts.

Keywords chosen from ICE Publishing list

Contracting, Procurement, Project Management

1. Introduction

1.1 Early-contractor involvement (ECI)

Integrating design and production has been a principle of lean design and construction inspired from Toyota Production System, which focuses on eliminating non-value adding activities and waste through the whole production system in the supply chain. Jorgensen and Emmitt (2007)'s ethnographic case studies identified crucial factors influencing effective lean integration. They include; identifying client values, project team and planning process, transparent decision-making, management and leadership, continuous learning, and establishing an appropriate project delivery framework. In particular, appropriate delivery framework is fundamental as it affects other factors with the incentives, resources (including time, financial means, and human and organizational resources), contracts, and others in order to integrate design and construction as an overall lean approach. Similarly this aligns with definitions of construction procurement decisions being the process of acquiring the resources required to realise a construction project (see the Australia and New Zealand Government Procurement Agreement 2013;). In addition, Toolanen (2008) included the choice of an appropriate governance structure, allocation of contractual obligations, and form of compensation.

Kirkham suggests in the *Civil Engineering Procedure 7th edition* (Kirkham, 2016) suggest that early-contractor involvement (ECI) denotes "… a non-traditional procurement route, where a contractor's skills are introduced early into a project to bring design 'buildability' and cost efficiencies to the pre-construction phase". The term ECI may be used as a concept to describe any procurement strategy that involves the contractor during the design phase, such as design and build, management contracting, or construction management, or as its own procurement system, typically referred to as two-stage procurement process, such as the 'conditional' pre-construction contract promoted by Mosey (2011). This may be contrasted with the traditional single-stage tender model where contractors are invited to bid ***after*** designs are fully developed.

1.2 Construction and OSM in New Zealand

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The New Zealand (NZ) construction industry generates over $30 billion per annum (MBIE, 2013). It contributed over 6.3% of the GDP in 2010 growing from 5% in 2008. Being a significant industry in NZ, even a one percent saving in process efficiency could equate to a saving of up to $300 million per year, potentially without affecting the quality or delivery of the built asset. Despite this growth, there are considerable labour shortage, poor productivity issues and lack of effective project delivery. Similar to these issues in NZ, researchers elsewhere have emphasized the importance of the project delivery: Thomas, Luu and Chen (2002, p79) describe the selection and use of an appropriate procurement system as 'crucial to project success.'

The effectiveness of procurement strategies have been linked to productivity (Wilkinson and Scofield, 2010; The Building and Construction Productivity Partnership, 2012), innovation (Loosemore, 2014; de Valence, 2010), and the potential for conflict and disputes (Heaphy, 2011; Jelodar, Yiu and Wilkinson, 2015; Mosey, 2011). Internationally there are growing trends towards more use of off-site manufacturing to resolve many of these issues including labour shortage and productivity. The NZ construction industry is no exception (PrefabNZ, 2015)

Off-site manufacturing (OSM) is a form of modern method of construction (MMC) in which a key principle is to transfer work off-site. Forms of OSM include; modules or volumetric pods, panelised, hybrid, and sub-assemblies and components (Wilkinson and Scofield, 2010). Some of the benefits have been described by Wilkinson and Scofield (2010) including; reduced on-site congestion, shortened project durations, reduced time-related costs allowing for earlier building close-in, reduced labour costs, and improved quality through producing work in more controlled environments. However, there are numerous challenges associated with OSM. The design must be finalised earlier, making changes during the construction phase more difficult. In addition, tolerances can be difficult to maintain resulting in connectivity issues; transported units are subject to size and weight restrictions; units require protection during delivery and storage; and an increased reliance is placed on manufacturers to deliver when promised. Tradespeople who are passionate about their craft may be reluctant to adopt OSM processes.

Despite drivers toward the MMC concept, its uptake is not without challenges. Shahzad (2011) categorises the main barriers to the adoption of OSM in New Zealand into seven broad categories (in descending order of impact and relative contributions): industry and market culture (16.2%), skills and knowledge (15.5%), logistics and site operations (14.8%), cost/value/productivity (14%), supply chain and procurement (13.7%), process and programme (13.6%), and regulatory issues (12.2%). Under the category of industry and market culture, a conservative market approach and client mind set was found to be prominent constraints. Limited expertise of designers to handle OSM designs and a lack of experienced manufacturers were constraints under skills and knowledge. A lack of research and development into OSM was also noted. Design-related issues were the most prominent constraints under the process and programme. The main issue is that OSM design choices must be made during design development resulting in limited freedom to make design changes after the construction phase commences. Another issue relates to connectivity problems onsite and the potential "mismatch between design and the manufacturing process" (Shahzad, 2011, p47). Issues associated with transporting large modular or pre-fabricated units and site restrictions affecting space required for craneage and manoeuvrability of heavy plant and equipment were the most significant constraints under logistics and site operations. This correlates with the main constraints under the cost/value/productivity category, which include concerns about increased project costs for transportation of OSM units, particularly modular or large units, and for the increased use of craneage.

Most of the constraints including difficulties for designers to incorporate OSM technology, connectivity and potential mismatch between design and manufacturing, and issues with transportation and site restrictions may be summarized as design ***buildability*** issues. Some of these may also contribute to the first constraint – conservative market culture - particularly given the need to finalise design decisions earlier and the consequent difficulty to make changes during construction. Because OSM integrates design and manufacturing, it is critical to involve key constructors in the design process. Indeed, the integration of construction knowledge to maximise project performance is at the heart of definitions of 'constructability' (see CII, 1998;

CIIA, 1992) which, according to Jergeas (2009), is used interchangeably with the term 'buildability.'

Under single-stage procurement, clients risk commissioning a design which, when tendered, is found to be unnecessarily difficult or even impossible to build. Involving the constructor in design development may reduce this risk. A standard model may help overcome the most prominent barrier to OSM adoption, industry and market culture (16.2%), being a conservative market approach and client mind set, because standard forms of contract provide familiarity and can be tired and tested over time (Ashworth, 2012).

Through ECI, the works can be collaboratively planned, harnessing the contractor's buildability knowledge to foresee risks and maximise value (Laryea and Watermeyer, 2016; Pheng, Gao and Lin, 2015; Mosey, 2011; Rahmani, Khalfan and Maqsood, 2014; Whitehead, 2009; Song, et al., 2006). Specific information contributed by the contractor can include aspects such as resource availability and limitations in terms of cost, performance, access, and site conditions (Song, et al., 2009, p13). Benefits of such collaboration include; reducing disputes (Mosey, 2011), more transparent pricing (Mosey, 2011; Whitehead, 2009; Berends, 2006), reduced design changes, avoiding delays, and achieving pre-fabrication-to-erection schedules (Song, Mohamed and AbouRizk, 2009; Whitehead, 2009).

Despite all this, the ECI approaches lack clear definition. Debate exists around the extent that ECI should be considered as purely a partnership concept. In the UK, ECI is typically considered a form of partnering (Rahman and Alhassan 2012). Some propose that only a charter is required, however, Mosey (2011) argues that strategies should recognize the commercial interests of the contracting parties. Rahmani, Khalfan and Maqsood (2013, p2) describe a two-stage model where contractors are selected on a purely non-price basis to assist with project planning and develop an 'open book' target cost. In contrast, Pheng, Gao and Lin (2015) describe a two-stage approach that allows contractors' participation in the design process while maintaining competitive pricing. Contractors can be invited to tender a price based on a notional bill of quantities, then once the design is finalised, a firm bill of quantities is developed by applying the rates from the original tender.

There is currently no standard model for two-stage ECI in New Zealand. ECI contracts have generally remained confined to large infrastructure projects in countries such as Australia, New Zealand, UK, the Netherlands, and the United States (Rahmani, Khalfan and Maqsood, 2013). In Australia, Whitehead (2009) describes hybrid models where the first-stage is a form of partnering and the second stage is often a design and build contract. Examples of those that have adopted this approach include; South Australia's Department for Transport Energy and Infrastructure (DTEI) and Queensland's Department of Transport and Main Roads (TMR).

The Joint Contracts Tribunal (JCT) publishes the *MC Management Building Contract 2011* within its suite of contracts. However, this is a single contract, which covers both pre-construction and construction stages, rather than a two-stage process. It has also been criticized for its risk allocation approach and is reportedly the least use contract in the JCT suite of contracts (see Glover, 2013). The New Engineering Contract (NEC) suite also includes a management contract option: *NEC3: Engineering and Construction Contract Option F: management contract*. Unlike more traditional lump sum construction contracts, NEC (2014a) describes it as a "cost reimbursable management contract where the financial risk is taken largely by the client." In January 2016, NEC released a supplementary additional ECI clause for use with NEC contracts options C (target contract with activity schedule) and E cost reimbursable contract) (NEC, 2014b). The ECI clause provides basic pre-construction provisions. However, under the NEC FAQs webpage, (NEC, 2014c) clarify that the ECI clause is not suitable for use with lump sum contracts. The JCT Suite was updated in 2016 and NEC4 was released in 2017. However, the contractual amendments do not fundamentally effect the approaches to the JCT MC and CM contracts or the NEC ECI clause.

In 2011, the JCT launched, as part of its suite, the *Pre-Construction Services Agreement (General Contractor) (PCSA)* and *Pre-Construction Services Agreement (Specialist) (PCSA/SP)*. Like bespoke use in New Zealand, these act as a supplement to a standard form of construction contract - in this case, the JCT standard contracts for building works only or for design and build. The latest version of JCT's Pre-Construction Services Agreement (General Contractor) PCSA 2016 is described by the JCT as being designed for appointing a contractor to carry out pre-construction services under a two-stage tender process. The PCSA is claimed to enable the contractor to 'collaborate with the employer or their team of consultants to develop detailed designs, to develop the main contract works, or to compile specialist tender documents'. It also claims that the early contractor involvement enables the contractor to make preparation for the construction phase, such as the programme, cost plans, buildability and any specialist procurement.

These agreements provide a range of standard provisions and enable parties to set out the preconstruction services and methods of payment.

In New Zealand, an operations manager for a nationwide construction company estimates that 25-30 percent of their turnover in the Otago region is through two-stage ECI (personal communication, September 5, 2016). In the second-stage construction contract, where the contractor may be responsible for either design and build or construction only, the manager estimates that construction only is more common. This contrasts with Francis and Kiroff (2015) who researched perceptions of ECI in New Zealand and asserted that design and build is the most common form of ECI in New Zealand commercial construction.

1.3 Research strategy and what this adds to the body of knowledge

Procurement systems that enable ECI are evaluated in terms of how well they support OSM. A conceptual process model for two-stage ECI is developed. Key variables are identified from literature, three ethnographic case studies in Dunedin, Otago New Zealand between 2006 and 2017, and document analysis. The projects have construction costs ranging from approximately $10-20 million NZD. Two involved complex alterations and extensions with high levels of building services. The third is an accommodation building comprising prefabricated timber structure. The lead author worked as the head contractor's quantity surveyor in two projects between 2006 -2009. The range of pre-construction services is identified through open coding from ECI related literature. Legal doctrine is used to distinguish between obligations for design buildability versus design compliance with codes and standards. Each variable is considered in terms of optimal process based on theory and clarity of risk allocation. The conceptual model was presented at a conference and two further pre-construction services were added following feedback. Features of the model are aligned with overcoming the barriers to OSM adoption.

2. Procurement needs for OSM

It is generally agreed that there is no one perfect procurement strategy, rather, a strategy should be based on sensible policy (Murdoch and Hughes, 2008) and aligned with the client's requirements and the nature of their project (Kirkham, 2007). Decision-making criteria include:

- Involvement of the client with the construction process
- Separation of design from management
- Reserving the client's right to alter the specification
- Clarity of client's contractual remedies
- Complexity of the project
- Speed from inception to completion
- Certainty of price

A range of procurement pathways exists for any construction project. Given the lack of clear definitions, McDermott and Rowlinson (1999) describe the debate around whether the term 'system' or 'model' is appropriate to describe the options. Nevertheless, the following procurement 'models' are generally recognised; design and build (DB), traditional (general contracting), design and build, construction management (CM), and management contracting (MC). In DB, the contractor has single-point responsibility for both design and construction; in traditional contracting, the client employs a design team to produce the design which when complete is tendered to builders; in management contracting the head contractor subcontracts all trade packages allowing them to be involved during the design stage more like a consultant; in construction management, the client employs all the trade contractors directly and a consultant to manage them.

For clients and consultants to make informed design decisions on projects involving OSM, Elnaas, Ashton and Gidado (2009) recommend procurement practices should facilitate the sharing of cost and buildability knowledge among manufacturers, constructors and designers. Single-stage procurement fails to resolve the buildability constraints of OSM because the contractor does not see the design until it is already fully developed. Kirkham (2007) demonstrates clearly how the potential for added value diminishes and the cost of change increases as the design is developed.

The most prominent barrier to the uptake of OSM was the reluctance to adopt unfamiliar processes. Jergeas and Put (2001) found the risk aversion by owners and lack of knowledge of latest construction methods to be a key barrier to innovation. A key advantage of traditional lump sum contracts is that the procedures are well understood and the standard forms of construction contract provide familiarity and reliability through being well tried in case law (Ashworth, 2012; Kirkham, 2007). Traditional lump sum contracts remain the dominant contract form, accounting for about 75 percent of construction projects by number in the UK, with design and build the second most used at around 17.5 percent (RICS, 2010).

Therefore, the optimal procurement strategy to enhance OSM should enable contractor involvement in the design, effectively allocate the risks of design and buildability, enable competitive lump sum pricing, and be developed in the form of a standard model than can become familiar and tested over time. Procurement models that provide ECI include; design and build, MC, CM, partnering and alliance contracts, and general contracting with two-stage tenders.

3. Procurement systems suitable for OSM

Design and build procurement would be suitable for projects with OSM where the design is straightforward and changes during construction are unlikely. Under CM and MC the consultant or head contractor can provide input to the design around planning and buildability, while the client retains ownership of the design. The project can be fast-tracked by overlapping design and construction and OSM elements can be ordered in time to avoid delay. If pricing is equal, the reduced risk exposure of MC is advantageous over CM for lay clients. Under CM, the client employs the specialist contractors directly with a consultant to manage them and so adopts more risk than the single-point accountability of a head contractor.

Consultant construction managers do incur implied legal obligations, including; warning the client of poor performance by others in the project team (Chesham Properties v Bucknall Austin, 1996), coordinating trade works (Donohoe and Brooks, 2007); planning, monitoring and controlling activities and resources (Griffith and Watson, 2004); and warning the client of contractual risk (Monastiriotis & Bodnar, 2013; Plymouth & South West Co-Op Soc. Ltd v Architecture, Structure & Management Ltd, 2006). However, their duty is limited to taking *reasonable skill and care*, whereas a head contractor's liability is absolute or a fitness for purpose obligation. For example, contractors are responsible for any building defects and may be liable for liquidated or general damages. In contrast, if a project is delivered late under CM, the client must rely on the consultant having sufficiently accurate records to pinpoint the damages on individual trade contractors, or the client must prove that the breach is a consequence of the consultant's negligence (Monastiriotis and Bodnar, 2013). Moreover, Laryea (2010) found that contractors' buildability and pricing advice may be more accurate than that of consultants', on the basis that contractors perform the works and are contractually accountable for the accuracy of their estimates. This could be beneficial when comparing costs between OSM and traditional assemblies. A two-stage procurement process may be used to select a contractor for design and build, construction only or management only.

4. Findings: Key variables of pre-construction stage

From the case studies, key variables in first stage of the two-stage process include:

i. The scope of services to be provided by the contractor, such as; planning and sequencing the works, designing elements, providing buildability advice, risk management, value management, and procuring subcontractors;
ii. How or whether the contractor is reimbursed for their early input, such as; no payment, lump sum component of preliminaries, and cost reimbursement;

iii. Under what grounds the project may be terminated without proceeding to construction phase, such as; if over budget, external intervener groups;
iv. What happens if the project does not proceed to the construction phase, such as; the contractor does not charge for their early involvement, the contractor does not charge but is paid if the project does not proceed to construction, or the contractor does charge but offers a discount if the project does proceed to construction;
v. Whether the contractor is to perform any direct works (such as the head contractor performing concrete and carpentry works) and if so, how this is priced, such as; competitive lump sum or whether any fixed rates are to be provided against provisional quantities to be re-measured against the detailed design later;
vi. The clear allocation of design and buildability obligations;
vii. Who owns any intellectual property;
viii. Key milestones for providing information;
ix. Contractual provisions that encourage a collaborative culture, such as requiring parties to act in “good faith”, or “mutual trust and co-operation”.

The above model was presented at the Modular Construction and Pre-fabrication conference in Auckland, New Zealand December 2017. The following pre-construction services were suggested during the feedback session:

- Liaising with local authorities to obtain compliance for pre-fabricated components.
- Coordinating documentation for building information modelling (BIM).

The following sections expand on some of the variables and consider alternative options in terms of theory and risk allocation.

4.2 Pricing and timing

Head contractors were found to generally tender first-stage prices based on the following:

I. A lump sum price for the preliminaries works for the whole project where construction work is staged;

II. A lump sum price for the construction of any first stage for which design is already developed (for example where the project is released in stages);
III. Percentages to be applied for onsite and offsite overheads and profit to be applied to variations and subcontractors to be procured;
IV. Fixed rates for provisional quantities of any direct construction works (for example carpentry and concrete) based on conceptual design;
V. Non-price attributes such as a base construction program, methodology, and history of similar past projects;

Lump sum contracts provide price surety before work commences. Risks are transferred to the contractor with narrow grounds under which the contractor can claim additional costs or time. In a cost reimbursement contract, the contractor is paid based on agreed rates and percentages applied to materials and subcontractors. However, this may incentivize the contractor to overspend (Turner, 2004). A target value or guaranteed maximum price may be used with gain-share / pain-share provisions to align goals. However, auditing is required to ensure claims are accurate.

One argument for partnering with open-book pricing is that the lack of defined scope at the time of early involvement prohibits competitive pricing (Rahman and Alhassan, 2012, p218). However, lump sum pricing can be determined for preliminaries works so long as sufficient concept design exists to establish such requirements such as management, supervision, insurances, and temporary works. Head contractors can declare margins for profit and overheads to apply to subcontractors and variations, plus a lump sum construction price for any first-stage work already designed or fixed rates for carpentry and concrete works against a provisional schedule of quantities. The quantities can then be re-measured once the design is developed to produce a bill of quantities applying the rates of the original tender (see Pheng, Gao and Lin, 2015) and arrive at a lump sum construction price. Because the quantities are only provisional and will be re-measured, they could be measured by a consultant quantity surveyor or the contractor. The client or consultant will need to check the accuracy of the contractor’s final quantities.

Timing of contractor involvement is crucial to enabling competitive and accurate pricing. Some argue that to maximise value, contractors should be involved from “day one” of the design process (Jergeas and Put, 2001, p283). Others contend that a concept design is needed first because if the client has very specific ideas about the finished product, the contractor may have nothing to add, or may waste time developing proposals for a client who does not know what they want (Francis and Kiroff, 2015). If the contractor is appointed too early they might lack motivation to appoint their best staff and there can be a loss of design creativity if the team does not work well together and the designer steps back as the contractor pursues buildability and cost saving efficiencies (Whitehead, 2009). In addition it is arguable that generally designers prefer to work solely with their client to develop concept design (Francis and Kiroff, 2015). On the whole it is contended that the optimum time for contractor engagement is once sufficient conceptual design exists to enable competitive lump sum pricing for preliminaries and fixed rates against provisional quantities for direct works. Delaying beyond this will reduce the contractor’s potential to evaluate design options.

4.3 Payment

One drawback of two-stage ECI is the client pays for the contractor earlier than they would under single-stage tenders and may pay for the contractor’s cost of pricing construction. However, when contractors tender in the open market, they incur the cost of tendering with a higher risk of not winning. Pricing the first-stage of ECI incurs fewer resources than preparing a full tender, and then if successful, the contractor works toward a well-planned project that they can be reasonably sure of proceeding. Therefore, why should the client pay for the contractor to price construction work under ECI? Figure 1 demonstrates the two-stage conceptual process model based on no payment for the pre-construction stage unless the project does not proceed to construction.

Insert Figure 1 here.

Figure 1: Two-stage ECI process model with no payment option for pre-construction stage

Laryea and Watermeyer (2016) provide case studies of two construction projects for Wits University in South Africa procured through two-stage ECI in which the contractor received “no remuneration for the involvement in design development” as, “they value the benefits of developing early cost models and production plans.” In one of the case studies, the lead author worked as a contractor’s quantity surveyor on a $9 million health project in 2006-2008 procured through two-stage ECI where the contractor did not charge for their early-involvement. The head contractor appointed in another of the case studies - a student accommodation project - is charging for their early involvement, but with a discount if the project proceeds to construction. Three options exist for first-stage pricing;

a) The contractor does not charge for their involvement; or
b) The contractor does not charge, but is reimbursed if the client does not progress the project to construction phase;
c) The contractor charges, but offers a discount if the project proceeds to construction phase.

Any first-stage price may be cost reimbursement or fixed price component of the lump sum preliminaries price.

4.4 Pre-construction services

Pre-construction services include the planning, design, and procurement activities that lead up to the physical construction work. These may include; planning and sequencing construction activities, design review and specialist design contributions, risk and value management, and subcontractor procurement. According to Mosey (2011) early stage contracts can support the project by setting out the head contractor and subcontractors’ contributions to buildability, affordability and design appropriateness, testing the scope for savings, and evaluating the viability of new ideas across the project’s whole life cycle. Mosey recommends that a communication plan be included and a program that includes deadlines for team members to provide information. This is echoed by The Centre of Construction Law and Dispute Resolution Kings College (2016) who recommend that any procurement processes to support BIM should;

set out key milestones for providing information, address who owns intellectual property; and provide contractual provisions that encourage collaboration. Pre-construction services have been open-coded from literature and are presented as follows:

Table 1: Pre-construction services open-coded from literature

Pre-construction services	Sources
Design management	Tzortzopoulos and Cooper (2007); Sidwell (1983)
Plan and co-ordinate design	Tzortzopoulos and Cooper (2007)
Stakeholder management and communications strategy	Tzortzopoulos and Cooper (2007); Mosey (2009); Education (2016); Berends (2006)
Develop design brief	Tzortzopoulos and Cooper (2007); Education.govt.nz (2017)
Construction planning	
Planning and sequencing construction activities	El-sayegh (2009); Mosey (2009); Kashiwagi, Kashiwagi and Savicky (2009); Sidwell (1983)
Buildability evaluation	Laryea and Watermeyer, (2016); Pheng, Gao and Lin (2015); Rahman and Alhassan (2012); Mosey, (2011); Rahmani, Khalfan and Maqsood (2014); Whitehead (2009); Song, et al. (2006); Jergeas and Put (2001); Sidwell (1983)
Financial	
Budget advice	Kirkham (2007); Laryea (2010); Sidwell (1983)
Value management	Mosey (2011); Kirkham (2007); Whitehead (2009); Jergeas and Put (2001); Kashiwagi, Kashiwagi and Savicky (2009)
Risk management	Rahman and Alhassan (2012); Mosey (2009); Education.govt.nz (2017); Jergeas and Put (2001); Kashiwagi, Kashiwagi and Savicky (2009)
Supply chain	
Subcontractor and supplier procurement	El-sayegh (2009); Whitehead (2009); Mosey (2009) ; Sidwell (1983)

If the head contractor becomes involved once concept design is developed, stakeholder management and developing the design brief must be done by the client's project manager or architect. The remainder could be specified for the contractor.

4.5 Obligations for design and buildability

A risk of adopting OSM technology involves unknown buildability issues rendering the design more expensive to construct than comparable traditional assemblies, or worse, tendering a fully developed design only to find that the design is not buildable.

The implied legal duty imposed on a designer or project manager is that of *reasonable skill and care*. The test is measured against what any other ordinarily skilled person in the same discipline would have done given similar circumstances (Powell, 2009; Read, 2004; Bolam, 1957).

The implied legal duty imposed for construction work is *fitness for purpose*. Fitness for purpose imposes a higher standard than that of reasonable skill and care. The standard is absolute guarantee of product performance imposed on manufacturers, which also falls onto contractors in the construction sector (Burrows, Finn and Todd, 2012). Where a contractor is also responsible for design, their implied legal duty defaults to fitness for purpose (Brown, 2011; Steensma, 2010). Therefore, where a manufacturer designs and supplies pre-fabricated modular or prefabricated elements, they are responsible for those elements being fit for their intended purpose and defect free, regardless of what any other designer would have done, unless the contract provides otherwise. Like most published standard forms of construction contracts around in the UK and many other Commonwealth jurisdictions, published construction contracts in New Zealand such as the NZS3910:2013 (clause 5.1.4), NZIA SCC 2014 (clause 8.6.5), and RMBF SA 2009 (clause 6.1.1) all reduce the liability for any contractor’s design work to that of *reasonable skill, care and diligence*.

Designers are responsible for ensuring that their design will perform according to relevant codes when constructed using reasonable standards or workmanship (George Fischer Holding Ltd v Multi Design Consultants Ltd (1998) and levels of supervision (Equitable Debenture Assets Corporation Ltd v William Moss Group Ltd, 1984). This is reflected in the New Zealand Building Act (2004) which requires designers to produce designs in compliance with the New Zealand Building Code (NZBC) when built using reasonable standards of workmanship.

By offering a lump sum price, a contractor warrants that (i) they can build what has been designed, and (ii) they can build it for the price offered. Anything that makes the work more difficult is the contractor’s risk including design defects from a buildability perspective (Rosenberg, 2012). Once appointed, contractors are legally required to notify the designer of certain design defects (Glover, 2006).

Standard forms of construction contracts commonly relieve the contractor for reasonably unforeseeable physical conditions that substantially affect the cost of the work. This would cover instances where the contractor uncovers unexpected rock during excavation work, or unexpected steel structure or asbestos when wall linings are removed. However, such provisions would unlikely cover re-designs required in the event of site restrictions making delivery of precast panels un-deliverable, or where pre-fabricated components are designed too large for manufacturing facilities, or where designed windows do not fit prepared openings due to connectivity issues with the design. The first-stage pre-construction contract provides an opportunity to address these risks.

5. Conclusions

Early contractor involvement (ECI) offers significant advantages for projects that use OSM technologies. Designers and contractors can work collaboratively in developing the design, managing risks, undertaking value management exercises, and procuring specialist subcontractors. The contractor can evaluate costs and buildability of design options, for example comparing OSM technology with more traditional assemblies, and adopt clearer contractual responsibility for design buildability than is afforded under many standard forms of construction contracts. The more integrated approach overcomes current segmentation and enables client and designers to make more informed decisions about adopting OSM and can reduce the potential for potential future buildability problems and related variations and disputes during construction. Depending on whether or how the contractor is paid for their early involvement there may be little or no additional cost to the client - recognizing the benefit to the contractor of a better planned and more buildable project.

Contract documentation for the first-stage of two-stage ECI should clearly set out among other things; (i) the scope of services to be provided by the contractor such as planning, budgeting, buildability evaluation, risk management, value management, and subcontractor procurement, (ii) key milestones for communication exchange and supply of elements, (iii) who owns intellectual property, (iv) whether or how the contractor is paid for their early-involvement, (v) under what grounds the client can terminate the project, (vi) what happens if the project does not proceed to the construction phase, and (vii) parties' obligations around design and construction, whether for individual elements or for the overall design, and the contractor's early notification of design issues.

Opportunity exists in New Zealand to develop a standard form of first-stage pre-construction contract for two-stage ECI procurement for use with a standard form of construction contract for the second stage (such as NZS3910:2013 or NZIA SCC 2014). This could help overcome the barrier to OSM relating to conservative market culture by becoming familiar and tested over time. Provision for competitive lump sum pricing across all tiers of the supply chain may also suit risk adverse clients. To the extend a standard model for two-stage ECI becomes recognised for reducing design buildability risk, it is conceivable that in extreme cases consultants could potentially be held negligent for not recommending ECI processes for complex projects for exposing their client to unjustifiable design buildability risks.

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