

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, FCIQB, FCI Arb, 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, MCIQB, 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

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

30 The New Zealand (NZ) construction industry generates over \$30 billion per annum (MBIE,
31 2013). It contributed over 6.3% of the GDP in 2010 growing from 5% in 2008. Being a significant
32 industry in NZ, even a one percent saving in process efficiency could equate to a saving of up to
33 \$300 million per year, potentially without affecting the quality or delivery of the built
34 asset. Despite this growth, there are considerable labour shortage, poor productivity issues and
35 lack of effective project delivery. Similar to these issues in NZ, researchers elsewhere have
36 emphasized the importance of the project delivery: Thomas, Luu and Chen (2002, p79) describe
37 the selection and use of an appropriate procurement system as 'crucial to project success.'

38

39 The effectiveness of procurement strategies have been linked to productivity (Wilkinson and
40 Scofield, 2010; The Building and Construction Productivity Partnership, 2012), innovation
41 (Loosemore, 2014; de Valence, 2010), and the potential for conflict and disputes (Heaphy,
42 2011; Jelodar, Yiu and Wilkinson, 2015; Mosey, 2011). Internationally there are growing trends
43 towards more use of off-site manufacturing to resolve many of these issues including labour
44 shortage and productivity. The NZ construction industry is no exception (PrefabNZ, 2015)

45

46 Off-site manufacturing (OSM) is a form of modern method of construction (MMC) in which a key
47 principle is to transfer work off-site. Forms of OSM include; modules or volumetric pods,
48 panelised, hybrid, and sub-assemblies and components (Wilkinson and Scofield, 2010).

49 Some of the benefits have been described by Wilkinson and Scofield (2010) including; reduced
50 on-site congestion, shortened project durations, reduced time-related costs allowing for earlier
51 building close-in, reduced labour costs, and improved quality through producing work in more
52 controlled environments. However, there are numerous challenges associated with OSM. The
53 design must be finalised earlier, making changes during the construction phase more difficult. In
54 addition, tolerances can be difficult to maintain resulting in connectivity issues; transported units
55 are subject to size and weight restrictions; units require protection during delivery and storage;
56 and an increased reliance is placed on manufacturers to deliver when promised. Tradespeople
57 who are passionate about their craft may be reluctant to adopt OSM processes.

58

59 Despite drivers toward the MMC concept, its uptake is not without challenges. Shahzad (2011)
60 categorises the main barriers to the adoption of OSM in New Zealand into seven broad
61 categories (in descending order of impact and relative contributions): industry and market
62 culture (16.2%), skills and knowledge (15.5%), logistics and site operations (14.8%),
63 cost/value/productivity (14%), supply chain and procurement (13.7%), process and programme
64 (13.6%), and regulatory issues (12.2%). Under the category of industry and market culture, a
65 conservative market approach and client mind set was found to be prominent constraints.
66 Limited expertise of designers to handle OSM designs and a lack of experienced manufacturers
67 were constraints under skills and knowledge. A lack of research and development into OSM
68 was also noted. Design-related issues were the most prominent constraints under the process
69 and programme. The main issue is that OSM design choices must be made during design
70 development resulting in limited freedom to make design changes after the construction phase
71 commences. Another issue relates to connectivity problems onsite and the potential “mismatch
72 between design and the manufacturing process” (Shahzad, 2011, p47). Issues associated with
73 transporting large modular or pre-fabricated units and site restrictions affecting space required
74 for craneage and manoeuvrability of heavy plant and equipment were the most significant
75 constraints under logistics and site operations. This correlates with the main constraints under
76 the cost/value/productivity category, which include concerns about increased project costs for
77 transportation of OSM units, particularly modular or large units, and for the increased use of
78 craneage.

79

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

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

90

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

97

98 Through ECI, the works can be collaboratively planned, harnessing the contractor's buildability
99 knowledge to foresee risks and maximise value (Laryea and Watermeyer, 2016; Pheng, Gao
100 and Lin, 2015; Mosey, 2011; Rahmani, Khalfan and Maqsood, 2014; Whitehead, 2009; Song, et
101 al., 2006). Specific information contributed by the contractor can include aspects such as
102 resource availability and limitations in terms of cost, performance, access, and site conditions
103 (Song, et al., 2009, p13). Benefits of such collaboration include; reducing disputes (Mosey,
104 2011), more transparent pricing (Mosey, 2011; Whitehead, 2009; Berends, 2006), reduced
105 design changes, avoiding delays, and achieving pre-fabrication-to-erection schedules (Song,
106 Mohamed and AbouRizk, 2009; Whitehead, 2009).

107

108 Despite all this, the ECI approaches lack clear definition. Debate exists around the extent that
109 ECI should be considered as purely a partnership concept. In the UK, ECI is typically
110 considered a form of partnering (Rahman and Alhassan 2012). Some propose that only a
111 charter is required, however, Mosey (2011) argues that strategies should recognize the
112 commercial interests of the contracting parties. Rahmani, Khalfan and Maqsood (2013, p2)
113 describe a two-stage model where contractors are selected on a purely non-price basis to assist
114 with project planning and develop an 'open book' target cost. In contrast, Pheng, Gao and Lin
115 (2015) describe a two-stage approach that allows contractors' participation in the design
116 process while maintaining competitive pricing. Contractors can be invited to tender a price

117 based on a notional bill of quantities, then once the design is finalised, a firm bill of quantities is
118 developed by applying the rates from the original tender.

119

120 There is currently no standard model for two-stage ECI in New Zealand. ECI contracts have
121 generally remained confined to large infrastructure projects in countries such as Australia, New
122 Zealand, UK, the Netherlands, and the United States (Rahmani, Khalfan and Maqsood, 2013).

123 In Australia, Whitehead (2009) describes hybrid models where the first-stage is a form of
124 partnering and the second stage is often a design and build contract. Examples of those that
125 have adopted this approach include; South Australia's Department for Transport Energy and
126 Infrastructure (DTEI) and Queensland's Department of Transport and Main Roads (TMR).

127

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

143

144 In 2011, the JCT launched, as part of its suite, the *Pre-Construction Services Agreement*
145 *(General Contractor) (PCSA)* and *Pre-Construction Services Agreement (Specialist)*
146 *(PCSA/SP)*. Like bespoke use in New Zealand, these act as a supplement to a standard form of

147 construction contract - in this case, the JCT standard contracts for building works only or for
148 design and build. The latest version of JCT's Pre-Construction Services Agreement (General
149 Contractor) PCSA 2016 is described by the JCT as being designed for appointing a contractor
150 to carry out pre-construction services under a two-stage tender process. The PCSA is claimed
151 to enable the contractor to 'collaborate with the employer or their team of consultants to develop
152 detailed designs, to develop the main contract works, or to compile specialist tender
153 documents'. It also claims that the early contractor involvement enables the contractor to make
154 preparation for the construction phase, such as the programme, cost plans, buildability and any
155 specialist procurement.

156

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

159

160 In New Zealand, an operations manager for a nationwide construction company estimates that
161 25-30 percent of their turnover in the Otago region is through two-stage ECI (personal
162 communication, September 5, 2016). In the second-stage construction contract, where the
163 contractor may be responsible for either design and build or construction only, the manager
164 estimates that construction only is more common. This contrasts with Francis and Kiroff (2015)
165 who researched perceptions of ECI in New Zealand and asserted that design and build is the
166 most common form of ECI in New Zealand commercial construction.

167

168 **1.3 Research strategy and what this adds to the body of knowledge**

169 Procurement systems that enable ECI are evaluated in terms of how well they support OSM. A
170 conceptual process model for two-stage ECI is developed. Key variables are identified from
171 literature, three ethnographic case studies in Dunedin, Otago New Zealand between 2006 and
172 2017, and document analysis. The projects have construction costs ranging from approximately
173 \$10-20 million NZD. Two involved complex alterations and extensions with high levels of
174 building services. The third is an accommodation building comprising prefabricated timber
175 structure. The lead author worked as the head contractor's quantity surveyor in two projects
176 between 2006 -2009. The range of pre-construction services is identified through open coding

177 from ECI related literature. Legal doctrine is used to distinguish between obligations for design
178 buildability versus design compliance with codes and standards. Each variable is considered in
179 terms of optimal process based on theory and clarity of risk allocation. The conceptual model
180 was presented at a conference and two further pre-construction services were added following
181 feedback. Features of the model are aligned with overcoming the barriers to OSM adoption.

182
183

2. Procurement needs for OSM

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

- 187 • Involvement of the client with the construction process
- 188 • Separation of design from management
- 189 • Reserving the client's right to alter the specification
- 190 • Clarity of client's contractual remedies
- 191 • Complexity of the project
- 192 • Speed from inception to completion
- 193 • Certainty of price

194

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

206

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

214

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

223

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

230

231 **3. Procurement systems suitable for OSM**

232 Design and build procurement would be suitable for projects with OSM where the design is
233 straightforward and changes during construction are unlikely. Under CM and MC the consultant
234 or head contractor can provide input to the design around planning and buildability, while the
235 client retains ownership of the design. The project can be fast-tracked by overlapping design
236 and construction and OSM elements can be ordered in time to avoid delay. If pricing is equal,

237 the reduced risk exposure of MC is advantageous over CM for lay clients. Under CM, the client
238 employs the specialist contractors directly with a consultant to manage them and so adopts
239 more risk than the single-point accountability of a head contractor.

240

241 Consultant construction managers do incur implied legal obligations, including; warning the
242 client of poor performance by others in the project team (Chesham Properties v Bucknall Austin,
243 1996), coordinating trade works (Donohoe and Brooks, 2007); planning, monitoring and
244 controlling activities and resources (Griffith and Watson, 2004); and warning the client of
245 contractual risk (Monastiriotis & Bodnar, 2013; Plymouth & South West Co-Op Soc. Ltd v
246 Architecture, Structure & Management Ltd, 2006). However, their duty is limited to taking
247 *reasonable skill and care*, whereas a head contractor's liability is absolute or a fitness for
248 purpose obligation. For example, contractors are responsible for any building defects and may
249 be liable for liquidated or general damages. In contrast, if a project is delivered late under CM,
250 the client must rely on the consultant having sufficiently accurate records to pinpoint the
251 damages on individual trade contractors, or the client must prove that the breach is a
252 consequence of the consultant's negligence (Monastiriotis and Bodnar, 2013). Moreover,
253 Laryea (2010) found that contractors' buildability and pricing advice may be more accurate than
254 that of consultants', on the basis that contractors perform the works and are contractually
255 accountable for the accuracy of their estimates. This could be beneficial when comparing costs
256 between OSM and traditional assemblies. A two-stage procurement process may be used to
257 select a contractor for design and build, construction only or management only.

258

259 **4. Findings: Key variables of pre-construction stage**

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

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

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

281

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

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

287

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

290

291 **4.2 Pricing and timing**

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

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

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

303

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

311

312 One argument for partnering with open-book pricing is that the lack of defined scope at the time
313 of early involvement prohibits competitive pricing (Rahman and Alhassan, 2012, p218).

314 However, lump sum pricing can be determined for preliminaries works so long as sufficient
315 concept design exists to establish such requirements such as management, supervision,
316 insurances, and temporary works. Head contractors can declare margins for profit
317 and overheads to apply to subcontractors and variations, plus a lump sum construction price for
318 any first-stage work already designed or fixed rates for carpentry and concrete works against a
319 provisional schedule of quantities. The quantities can then be re-measured once the design is
320 developed to produce a bill of quantities applying the rates of the original tender (see Pheng,
321 Gao and Lin, 2015) and arrive at a lump sum construction price. Because the quantities are only
322 provisional and will be re-measured, they could be measured by a consultant quantity surveyor
323 or the contractor. The client or consultant will need to check the accuracy of the contractor's
324 final quantities.

325

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

340

341 **4.3 Payment**

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

351

352 Insert Figure 1 here.

353

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

355

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

365

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

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

373

374 **4.4 Pre-construction services**

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

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

388

389 **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)

390

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

394

395 **4.5 Obligations for design and buildability**

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

399

400 The implied legal duty imposed on a designer or project manager is that of *reasonable skill and*
 401 *care*. The test is measured against what any other ordinarily skilled person in the same

402 discipline would have done given similar circumstances (Powell, 2009; Read, 2004; Bolam,
403 1957).

404

405 The implied legal duty imposed for construction work is *fitness for purpose*. Fitness for purpose
406 imposes a higher standard than that of reasonable skill and care. The standard is absolute
407 guarantee of product performance imposed on manufacturers, which also falls onto contractors
408 in the construction sector (Burrows, Finn and Todd, 2012). Where a contractor is also
409 responsible for design, their implied legal duty defaults to fitness for purpose (Brown, 2011;
410 Steensma, 2010). Therefore, where a manufacturer designs and supplies pre-fabricated
411 modular or prefabricated elements, they are responsible for those elements being fit for their
412 intended purpose and defect free, regardless of what any other designer would have done,
413 unless the contract provides otherwise. Like most published standard forms of construction
414 contracts around in the UK and many other Commonwealth jurisdictions, published construction
415 contracts in New Zealand such as the NZS3910:2013 (clause 5.1.4), NZIA SCC 2014 (clause
416 8.6.5), and RMBF SA 2009 (clause 6.1.1) all reduce the liability for any contractor's design work
417 to that of *reasonable skill, care and diligence*.

418

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

425

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

431

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

441

442 **5. Conclusions**

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

455

456 Contract documentation for the first-stage of two-stage ECI should clearly set out among other
457 things; (i) the scope of services to be provided by the contractor such as planning, budgeting,
458 buildability evaluation, risk management, value management, and subcontractor procurement,
459 (ii) key milestones for communication exchange and supply of elements, (iii) who owns
460 intellectual property, (iv) whether or how the contractor is paid for their early-involvement, (v)
461 under what grounds the client can terminate the project, (vi) what happens if the project does

462 not proceed to the construction phase, and (vii) parties' obligations around design and
463 construction, whether for individual elements or for the overall design, and the contractor's early
464 notification of design issues.

465

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

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