

# *Latent provisions for building information modeling (BIM) contracts: a social network analysis approach*

Article

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# 1 Latent Provisions for Building Information Modeling (BIM) Contracts: A 2 Social Network Analysis Approach

3  
4 Su-Ling Fan\*\*\*\*, Heap-Yih Chong\*\*, Pin-Chao Liao\*+, Cen-Ying Lee\*\*\*

## 6 Abstract

7  
8 The effective adoption and use of Building Information Modeling (BIM) require appropriate  
9 contract design to fairly allocate the contracting parties' rights and responsibilities. Several  
10 standards for BIM protocols and contracts have been developed for the industry. However, the  
11 awareness and the use of these are rather limited, leading to unclear provisions in BIM  
12 contracts. Therefore, the research aims to identify the influential legal aspects that serve as the  
13 latent contract provisions in BIM contracts. A questionnaire survey was conducted to survey  
14 experts and active BIM users in construction projects. The data were analyzed using social  
15 network analysis (SNA) by assuming interdependent relationships among various the legal  
16 aspects in BIM contracts. The key legal aspects associated with BIM contracts pertain to the  
17 roles and responsibilities of the project participants. The results also reveal that data security is

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18 the center of all latent legal aspects in the contracts. The study provides significant new insights  
19 into clarifying the required contract provisions in BIM contracts.

20

21 **Keywords:** BIM, legal aspects, contract provisions, contract administration

22

## 23 1. Introduction

24 Building information modeling (BIM) has been widely accepted in the architecture,  
25 engineering, construction, and operation (AECO) industry. However, most construction  
26 professionals are still unaware of the legal implications arising from BIM adoption. (Lowe and  
27 Muncey, 2009; Chew and Riley, 2013). Although several BIM protocols and contracts have  
28 been developed such as Joint Contracts Tribunal Public Sector Supplement (JCT, 2011),  
29 Document E203 TM -2013 – BIM and Digital Data Exhibit (AIA, 2013), ConsensusDocs  
30 301—Building Information Modeling addendum (ConsensusDocs, 2013), AEC BIM Protocol  
31 (AEC, 2012), CIC BIM Protocol (CIC, 2013) and Complex Construction Contracts (CPC,  
32 2013), the actual use of the protocols remains low (Al-Shammari, 2014). Previous related  
33 works mainly focused on the identification of potential BIM's legal risks (Hsu et al., 2015),  
34 legal implications in BIM implementation (Olatunji, 2011; Arensman and Ozbek, 2012; Eadie  
35 et al., 2015), adverse legal consequences in BIM contracts (Joyce and Houghton, 2014; Ussing  
36 et al, 2016), BIM's contractual arrangements (Kuiper and Holzer, 2013) intellectual property  
37 rights for BIM's copyright and ownership (Fan 2013) and a preliminary contractual framework  
38 for BIM-enabled projects (Chong et al., 2017). These studies showed that research into BIM  
39 contracts and the related legal aspects are still at a preliminary stage of development. It is vital  
40 to extend the previous research and make clear the important legal aspects which must be  
41 considered when devising BIM contracts.

42           The aims of this research is to identify the influential legal aspects that serve as the latent  
43 contract provisions in BIM contracts. A questionnaire survey method was adopted to collect  
44 the empirical data from BIM active users and experts in Taiwan due to the popularity of BIM  
45 in that area (Chien et al., 2014). Subsequently, the data were analyzed using social network  
46 analysis (SNA). SNA is an effective tool for investigating complex networks that involve the  
47 interdependence of actors in social structures and non-social structure analysis (Lee et al.,  
48 2018). This method was adopted to identify the important legal aspects by assuming the  
49 interdependency relationships and flows among the legal aspects (nodes). The study would  
50 offer insightful references to practitioners on the important legal aspects to be used as contract  
51 provisions when designing BIM contracts.

52

## 53   2.    Legal Aspects and Contract Provisions

54           BIM is an emerging technology in the building sector. However, the management of BIM  
55 practice is rather challenging and unstructured. It triggers numerous legal issues throughout the  
56 project lifecycle. An effective contract administration is one of the keys to regulating the new  
57 BIM practice via the written contract provisions. The contract provisions are effectively used  
58 to govern the legal issues and enforce necessary procedures required in BIM-enabled projects.  
59 Hence, it should identify and clarify the important legal aspects of BIM practices. Following a  
60 thorough literature review, the related legal aspects can be classified into three main categories,  
61 namely, (a) contract structure and policy, (b) contractual relationships and obligations, and (c)  
62 BIM model and security.

63

64

65

### 66   2.1   Contract structure and policy

67           BIM's contract structure and policy are used to govern the digitalized and collaborative  
68 attributes. The existing BIM contract protocols provide new perspectives in governing project  
69 stakeholders; but there are still unclear policies to accommodate the changed project  
70 requirements (Redmond et. al., 2010). A different legal framework is required to clarify the  
71 procurement and contracting methodologies (Kuiper and Holzer, 2013). A popular legal  
72 framework has been initiated and promoted in the industry for BIM enabled-projects, which is  
73 called Integrated Project Delivery (IPD) (BuildingSMART-Australasia, 2012). However, IPD  
74 is not the only procurement that suits the BIM practice as different working cultures and the  
75 maturity of BIM use should be taken into account when determining an appropriate framework  
76 (Chong et al. 2016). Furthermore, IPD contracts are generally prepared in an ad hoc and  
77 complicated manner, which might not be generalized for all types of projects (Smith, 2014).  
78 This might be the reason for this procurement system or legal framework being unpopular in  
79 BIM-enabled projects. Consequently, certain legal aspects need to be considered to cope with  
80 this situation.

81

## 82 2.2 Contractual relationships and obligations

83           The development of a BIM model is a joint effort by several parties. In a common  
84 practice, a BIM execution plan will explain the details of the necessary checklist and standards  
85 for the project implementation. Unfortunately, this document generally does not form part of  
86 the contract (Hardin and McCool, 2015). The unclear roles and responsibilities give rise to  
87 legal liabilities (McAdam, 2010), including pure economic loss (Simonian and Korman, 2010).  
88 Hence, the contractual relationships need to be clarified especially for the key stakeholders  
89 (including the BIM manager), which will help to regulate the required responsibilities or  
90 functions in the BIM Execution Plan (Lowe and Muncney, 2009). This situation could then

91 trigger another legal question on the need for additional insurance coverage throughout the  
92 development of BIM model (Enegbuma and Ali, 2011).

93 Besides, the standard of care needs to make clear for the project stakeholders when the  
94 liabilities and obligations have been regulated in the contract, (Hsieh et al., 2012). The common  
95 doctrines, namely, privity of contract and the *Spearin* doctrine can be referred and used to  
96 govern the stakeholders' duties. For example, a designer may not be able to claim the lack of  
97 privity of contract for his or her defense, especially under a collaborative system (Simoniam  
98 and Korman, 2010). As for the *Spearin* doctrine, it can be used by contractors as a legal defense  
99 to an employer's claim of nonconforming works (Barthet, 2010).

100

### 101 2.3 BIM model and security

102 One of the keys to BIM success is its digitalized data. The BIM information is digitalized  
103 and parameterized, such that the information can be easily extracted and reused either in whole  
104 or in part (Fan, 2014). Therefore, it raises a new problem about how the business knowledge  
105 can be protected. The security and privacy issues should not be ignored (Mahamadu et al.,  
106 2013). A common quick-response code (QR-Code) has been successfully integrated with BIM  
107 for optimizing the BIM model's information flow (Lorenzo et al., 2014). It can be used to  
108 prevent any infringements or copyrights issues related to the drawings and documents.  
109 Furthermore, a data-exchange plan is required to avoid transferring any unnecessary or  
110 incorrect information from the BIM model (Greenwood et al., 2010). The data-exchange plan  
111 should also address common interoperability issues; even though the Industry Foundation  
112 Classes (IFC) data modeling format has been developed as an open and neutral data format for  
113 the data exchange for BIM models (Steel et al., 2012).

114 Apart from that, a third party may incur an infringement claim from the model. It is  
115 advised that to make clear the intellectual property rights at the outset of the model

116 development. The available BIM contract protocols such as ConsensusDOCS 301 BIM  
117 Addendum and AIA Document E202 envisage that each party should own his/her rights as per  
118 the personal contribution. It also needs to comply with local statutory law or regulations in  
119 relation to data privacy and security (Fan, 2014). Therefore, all digital data should be well-kept  
120 and controlled. In addition, indemnity should be provided to protect the client's interests in the  
121 BIM model.

122

### 123 3. Research Methodology

124 None of the previous studies has considered the interdependent relationships among the  
125 key legal aspects of BIM. Most of the SNA-related studies, particularly in construction  
126 research, were qualitatively defined the strength of nodes (e.g. risks, stakeholders, etc.). This  
127 study used SNA to identify latent contract provisions based on the interdependent relationships  
128 measured by the covariance of expert opinions on each legal aspect. The steps of analyzing  
129 data are as follows: (a) identification of contract provisions; (b) development of association  
130 matrix, and (c) visualizations of association network. Consequently, a structured questionnaire  
131 survey method was selected to obtain the primary data

132

#### 133 3.1 Identification of legal aspects

134 We relied on the existing measurement scales of the key legal aspects for the  
135 questionnaire design, for which the legal aspects have been validated in prior research (Chong  
136 et al., 2017). The questionnaire was organized into two sections, namely, Section A which was  
137 used to investigate the background of the respondents, and Section B which was used to  
138 examine the levels of agreement on the identified thirty-four legal aspects (A1 to A34) and the  
139 appropriateness of the legal aspects of BIM contracts. The measurement items A1, A2, A3, A4,  
140 A15, and A16 were excluded in the questions pertaining to the appropriateness of the legal



141 aspects of BIM contracts as these were the legal issues associated with BIM contracts. The  
 142 five-point Likert scale, ranging from 1 (representing a zero of the trait; e.g. strongly disagree)  
 143 to 5 (representing a perfectly positive assessment of the trait; e.g., strongly agree) was  
 144 conducted by representing the points in weighting with values of -2, -1, 0, 1, and 2 respectively  
 145 in the analysis. Table I lists the measurement items of the legal aspects (Chong et al., 2017).

146

147 Table I Key legal aspects for BIM-enabled projects

| Code      | Legal Aspects                                                                                                                                      |
|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------|
| Aspect #1 | <b><u>Contract Structure and Policy</u></b>                                                                                                        |
| A1        | A specific standard form of contract is necessary to include the extent of all works and requirements of BIM; or                                   |
| A2        | Scope and requirements of BIM are sufficiently covered using an addendum.                                                                          |
| A3        | Scope and requirements of BIM should not be mandated with legal consequences; or                                                                   |
| A4        | The contract document should include digital data and information.                                                                                 |
| A5        | In case of any discrepancies, two-dimensional (2D) drawings shall prevail over three-dimensional (3D) drawings; or                                 |
| A6        | In case of any discrepancies, three-dimensional (3D) drawings with more details of the BIM model shall prevail over two-dimensional (2D) drawings; |
| A7        | Cost/payment of BIM should be charged based on a pre-determined proportion of the overall project cost; or                                         |
| A8        | Cost/payment of BIM should be charged based on the types of development, models, and functions required for the project; or                        |

- A9 Cost/payment of BIM should be charged based on the progress payment on the work done; or
- A10 Cost/payment of BIM should be charged based on the models' completion and its functions required in the project.
- A11 The standards/guidelines should be applied and followed throughout BIM model development.
- A12 A collaborative project delivery approach is required in BIM-enabled projects, such as IPD, partnering, etc.
- A13 The cost of developing the model, penalty, and rewards involved, if any, should be clarified earlier.

Aspect #2 **Contractual Relationships and Obligations**

- A14 A new role of BIM Manager should be engaged in the project.
- A15 The responsibilities and scopes of works of all parties involved should be specified in the contract.
- A16 The contract should stipulate the BIM's goals and quality audit for different stages of BIM model development.
- A17 The contractual relationship among the owner, designers, and contractors should be clearly specified and linked to the project.
- A18 The design team should not be responsible for negligence on the part of the design team. Such loss/damage should be recovered by the injured party or third party.
- A19 Any disclaimer clause is prohibited from excluding the design responsibilities for developing the BIM model.

- A20 The *Spearin* doctrine should be applied and upheld. The contractor should not be liable for the loss or damage because of insufficient information that he received or followed.
- A21 The designers should be responsible for the negligence towards the third party irrespective of Privity of Contract.
- A22 The contractor cannot make a claim from the design errors made by the designers which include pure economic loss.
- A23 Standard of care should be applied and upheld by all parties who develop or use the BIM Model.
- A24 Additional insurance is necessary to cover all risks and liabilities involved with BIM models, software, and hardware.
- Aspect #3 **BIM Model and Security**
- A25 A QR-Code should be used to prevent copyright infringement issues on the drawings and documents.
- A26 To prevent issues of interoperability, a BIM model should be developed before the project development stages, and a construction-ready BIM model should be created before the construction stage.
- A27 The designers who create the model own the copyright of the BIM model.
- A28 The authorized user can use, access and reproduce the model if permission has been sought from the copyright owner.
- A29 Each party owns all the rights to its own contribution if the model is designed and contributed to by a team.
- A30 The digital data and information should be protected with security for its usage and data integrity.

- A31 Certain constraints should be imposed to hinder data loss and protect privacy.
- A32 The data providers (designers or contractors) should be liable for the data included in the model.
- A33 The party who hosts the model should include the use and access, recordkeeping, warranty and preservation of the model for the agreed duration.
- A34 The owner should be indemnified because of data errors or technical issues arising from the use of BIM tools and software in the project.
- 

148

149 Subsequently, Taiwan was selected for the case study due to the popularity of BIM use  
150 in that country. The questionnaire was administered with convenience sampling through  
151 Taiwanese local governments. The respondents were carefully filtered and selected based on  
152 their actual experience or knowledge of BIM.

153

### 154 3.2 Development of association matrix

155 Any relationships between a pair of legal aspects should be pre-defined. Agenda-setting  
156 theory is referred, which is the ability of the news media to influence the salience of topics on  
157 the public agenda (McCombs and Reynolds, 2002). By referring to that theory, Guo et al.  
158 (2012) proposed the network agenda setting model (NASM), they asserted that information on  
159 the news or various kinds of media deliver a set of provisions or attributes and make them  
160 salient in the public's mind. This model was adopted in research areas of business  
161 communication (Meijer and Kleinnijenhuis, 2006), interpersonal communication (Vu and  
162 Gehrau, 2010), advertising (Buzan and Buzan, 1996), and crime (Lowry et al., 2003). Since  
163 NASM used co-existence as the indicator of interconnections among various provisions,

164 similarly, we used the covariance of evaluation on various legal aspects to be the level of their  
165 interdependencies. We assumed the covariance among the responses to the legal aspects as the  
166 input of SNA.

167 We utilized the absolute value of the Pearson product-moment correlation coefficient  
168 (PPMCC) derived from the responses as the indicator of the levels of interdependency among  
169 any pairs of legal aspects. This mimics the network-like structure regarding the associations of  
170 BIM related legal aspects in the minds of a group of people. The PPMCC ( $\rho_{v_i, v_j}$ ) illustrates  
171 the linear dependence between two variables  $v_i$  and  $v_j$  as shown by Eq. (1):

$$172 \quad \rho_{v_i, v_j} = \frac{\text{cov}(v_i, v_j)}{\sigma_{v_i} \sigma_{v_j}} \quad (1)$$

173

174 where cov represents the covariance and  $\sigma_{v_i}$  stands for the deviation in  $v_i$ .

175 According to the responses, we regard the larger the  $|\rho_{v_i, v_j}|$  as the stronger the  
176 interconnections between the pair of variables  $v_i$  and  $v_j$ .

177 Significant statistical relationships among two legal aspects may exist, however, the  
178 generic associations among content of the clauses may not reflect by covariance among  
179 responses. Therefore, a focus group consisting of five corporate and project managers was used  
180 to discuss whether the relationships and strength are either counterintuitive to practices. All of  
181 them have had more than 10 years of experience in BIM-enabled projects. The research  
182 background was first introduced at the beginning of the focus group meeting and a question-  
183 and-answer session was held to clarify the understanding of each pair of relationships. The  
184 statistically significant relationships of the dyads (pairs of legal aspects) were then further  
185 screened according to the following questions: 1) should any legal aspects of the dyad be a  
186 prerequisite or supplementary condition? 2) do the correlations among legal aspects reflect

187 actual practices? The above-mentioned questions were fully addressed by the focus group  
188 based on a consensus decision-making process.

189

### 190 3.3 Visualization of association network

#### 191 3.3.1 Network index

192 Density: Density (G) stands for the density value of network G, as given by Eq. 2. Here,  
193 K is the existing related pairs and N is the number of total variable items. The network density  
194 ranges from 0 to 1. A high density means that variable pairs are consistently coherent in the  
195 minds of the respondents.

196

$$197 \text{Density (G)} = K/(N(N - 1)) \quad (2)$$

198

199 Cohesion: Cohesion (G) refers to the condensed value of network G, as given by Eq. 3.  
200 AdjM is the adjacency matrix of network G. Z represents the average shortest-path between  
201 points. AdjM<sub>2</sub> is the number of connecting lines while Z is in the network. N is the total number  
202 of variable items. As the cohesion increases, so too does the complexity of the variable  
203 relationship.

204

$$205 \text{Cohesion (G)} = (\sum \text{AdjM}_z) / (N(N - 1)) \quad (3)$$

206

#### 207 3.3.2 Point/line index

208 Degree Centrality: This refers to the number of edges directly attached to a node. It is  
209 used to analyze the importance of a node from its leadership and influence positions within a  
210 network (Doloi, 2012). Nevertheless, degree centrality may not necessarily be a proxy for a  
211 node's leadership position (Solis et al., 2013). Hence, other measures must be used to determine

212 the importance and the saliency of the legal aspects. Degree centrality is expressed as in Eq.  
 213 (4):

$$C_D(p_i) = \sum_{k=1}^N a(p_i, p_k) \quad (4)$$

214  
 215

216 where,  $a(p_i, p_k) = 1$ , if there is a direct tie between  $p_i$  and  $p_k$  dan  $i \neq k$ .

217

218 **Betweenness Centrality:** This shows the effect of a given point/line between two points  
 219 or lines. A node with a high betweenness centrality value has some control over the network  
 220 as other nodes depend on that node to connect to each other (Chowdhury et al., 2011). The  
 221 betweenness centrality of the  $i$ th variable,  $v_i$ , is expressed by Eq. (5).

$$g(v_i) = \sum_{v_j \neq v_k} \frac{\sigma_{v_j v_k}(v_i)}{\sigma_{v_j v_k}} \quad (5)$$

222  
 223 where  $\sigma_{v_j v_k}$  is the total of the shortest path from variable  $v_j$  to variable  $v_k$  and  $\sigma_{v_j v_k}(v_i)$   
 224 represents the number of that path through  $v_i$ . This measures the gatekeeper role of  $v_i$ .

225 **Brokerage** considers the variable partitions. Using Gould & Fernandez's brokerage, one  
 226 can measure every triad and role of each variable in that triad for a specific partition vector. In  
 227 a contractual network, the partitions are categorized in various categories. These categories  
 228 are identified by measuring the number of times of each variable is numbered in the brokerage  
 229 relationships such as coordinator, gatekeeper, representative, itinerant, liaison.

230 **Coordinator:** If a variable  $v_i$  is correlated with another two variables  $v_j$  and  $v_k$  in the  
 231 same partition, then add one coordinator score to variable  $v_i$ . If either one of the  $v_j$  and  $v_k$  is  
 232 associated with  $v_i$ , add one gatekeeper or representative score to  $v_i$ . In both  $v_j$  and  $v_k$  are in  
 233 the same partition but different from  $v_i$ , and both are associated with  $v_i$ , then add 1 itinerant  
 234 score to  $v_i$ . Lastly, if  $v_j$ ,  $v_k$ , and  $v_i$  are in different partitions then add one liaison score to  $v_i$ .

235 Eigenvector Centrality: This is an extension of degree centrality and is proportional to  
 236 the sum of the centralities of a node's neighbors (Estrada and Rodríguez-Velázquez, 2005). It  
 237 assigns relative scores to all the nodes in the network based on the legal aspects that  
 238 connections to high-scoring nodes contribute more to the score of the node in question than  
 239 equal connections to low-scoring nodes. Eigenvector centrality is also used to identify the  
 240 importance of a practice by determining the feasibility of the said practice because of other  
 241 practices (Pishdad-Bozorgi et al., 2016) and the key trades (Wambeke et al., 2014). In  
 242 procurement networks, the actor with the highest eigenvector centrality score is considered the  
 243 most important member affecting the main pattern of the distances of all actors (Chowdhury et  
 244 al., 2011). Hence, eigenvector centrality is also considered as an important measure to identify  
 245 the influence of a legal aspect of the network. For a given graph,  $G: = (V,E)$  with  $|V|$  number  
 246 of vertices let  $A=(a_{v,t})$  be the adjacent matrix, i.e.  $a_{v,t} = 1$  if vertex  $v$  is linked to vertex  $t$ , and  
 247  $a_{v,t} = 0$  otherwise. The relative centrality score of vertex  $v$  can be defined by Eq. (6).

$$x_v = \frac{1}{\lambda} \sum_{t \in M(v)} x_t = \frac{1}{\lambda} \sum_{t \in G} a_{v,t} x_t \quad (6)$$

248 where  $M(v)$  is a set of neighbors of  $v$  and  $\lambda$  is a constant.

249 The degrees of the measures can help identify variables/nodes/contract provisions  
 250 which have a higher immediate impact on others. Interrelationships among these variables with  
 251 higher values of density cohesion, degree centrality, betweenness centrality, brokerage, and  
 252 eigenvector centrality should be managed (reviewed or revised) with higher attention.  
 253

254

#### 255 4. Results and Analysis

256 Thirty-six valid questionnaires were returned and used for the data analysis. This sample  
 257 size is sufficient when applying the central limit theorem based on its means value that  
 258 approaches the normal distribution. Table II shows that most of the respondents were aged



259 from within 41 to 60 (56%); some were below 40 (36%), and few were above 60 (8%). Their  
 260 occupations included architects (33%), consultants (28%), contractors (22%), educators (17%),  
 261 developers (3%), and government employers (3%). Most of the respondents had attained a  
 262 post-graduate level of education (61%) and had more than ten years working experience in the  
 263 construction industry (67%).

264 Table II Demographic information of subjects

| Age      | Subjects in the sample (%) | Occupation                                           | Subjects in the sample (%) |
|----------|----------------------------|------------------------------------------------------|----------------------------|
| Below 30 | 5.5                        | Architects                                           | 33                         |
| 31 to 40 | 30.5                       | Consultants                                          | 28                         |
| 41 to 50 | 36                         | Contractors                                          | 22                         |
| 51 to 60 | 20                         | Developers                                           | 3                          |
| Above 61 | 8                          | Educators                                            | 17                         |
|          |                            | Government or government-owned corporation employers | 3                          |

265

266 Subsequently, SNA was used to analyze the questionnaire data. Table III lists the evenly  
 267 distributed variables across the legal aspects.

268

269 Table III: Results of network analysis

| Legal Aspects                             | Number of Variables |
|-------------------------------------------|---------------------|
| Contract Structure and Policy             | 13                  |
| Contractual Relationships and Obligations | 11                  |
| BIM Model and Security                    | 10                  |

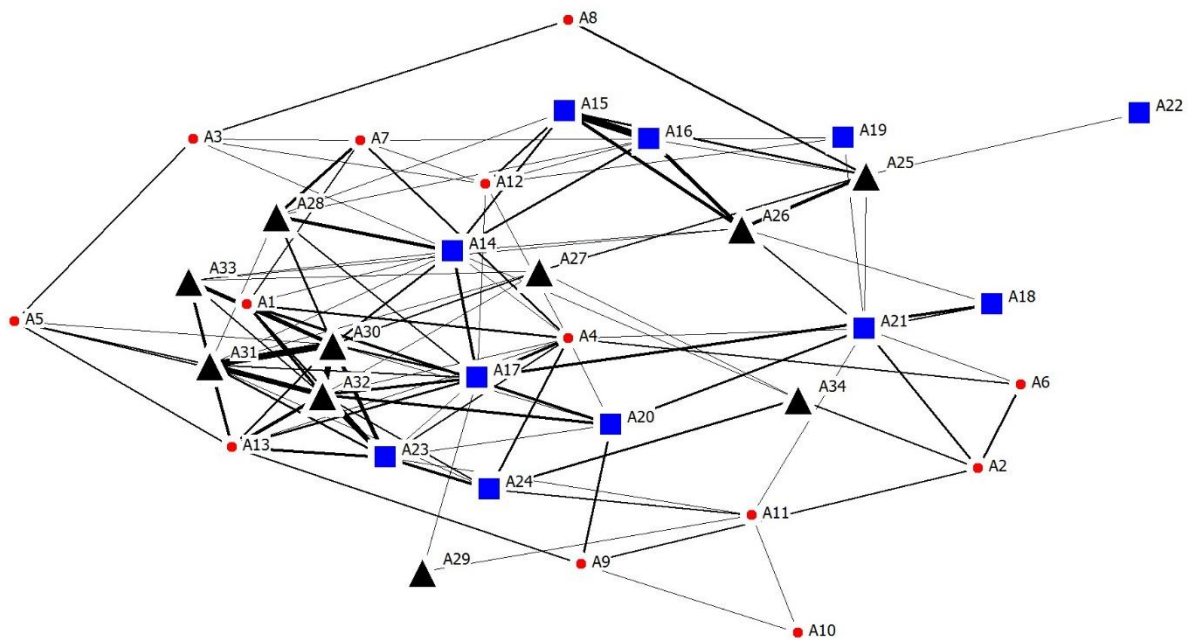
270

271

272 4.1 Network structure

273 Fig. 1 illustrates the interdependent network. The relationships were measured by  
274 PPMCC ( $p < 0.05$ ). The size of the nodes represents the degree centrality, while the shape and  
275 color indicate the type of legal variables (red circle = structure and policy, blue square =  
276 relationship and obligations, and black triangle = model, and security). The thickness of the  
277 edges represents the level of strengths interlinked two legal aspects. As shown in Table IV, the  
278 density of the risk network equals 0.47;  $SD = 0.1$  and therefore this network is regarded as  
279 being very dense. If the density is between 0 and 0.25, the network is regarded as having a low  
280 density (Wellman, 1976). Network centralization accounted for only 13.03%. It shows that  
281 there is low centralization among the legal aspects with greater centrifugal forces and smaller  
282 centripetal forces. On average, these variables are connected by 2.19 walks. This means that  
283 any two legal aspects can only be connected through two or more legal aspects. Table IV lists  
284 the interdependent network metrics.

285



286

287 Fig.1: Association network visualized with degree centrality

288

Table IV Summary of Network Metrics

| Network Metrics | Value      |
|-----------------|------------|
| Density         | 0.47       |
| Cohesion        | 0.54       |
| Centralization  | 13.03%     |
| Steps           | 2.19 walks |

290

291 From the dimensions of the network structure, the density value represents an average  
292 level of possible relationships in the network. This shows the possibility of some provisions  
293 interrelating with each other. The network has a cohesion value of 0.54, which is larger than  
294 the density value. There are strong direct interrelationships (indicated by the thickness of the  
295 ties) among the legal aspects in relation to BIM model and security. These legal aspects include  
296 security of digital data usage and its integrity should be protected (A30), restrictions should be  
297 imposed to reduce the loss of data and its privacy (A31), data providers should be responsible  
298 for any data provided by them and which is included in the BIM model (A32), and the host of  
299 the model should be responsible to use, access, maintain, warrant, and retain the model for the  
300 agreed duration (A33). For contractual relationships and obligations, the robust links are found  
301 among these three legal aspects such as, roles and scope of works for parties involved (A15)  
302 and goals of BIM and its quality checks in various stages of development (A16) should be  
303 defined in the contract. To prevent interoperability issues in the post-construction stage, the  
304 BIM model should be developed ahead of all the development stages, particularly before the  
305 construction stage (A26). The strong interrelationships among the above legal aspects indicate  
306 that they are dependent on each other. The design of BIM contracts would not be complete  
307 without linking these legal aspects.

308

309           4.2       Degree Centrality

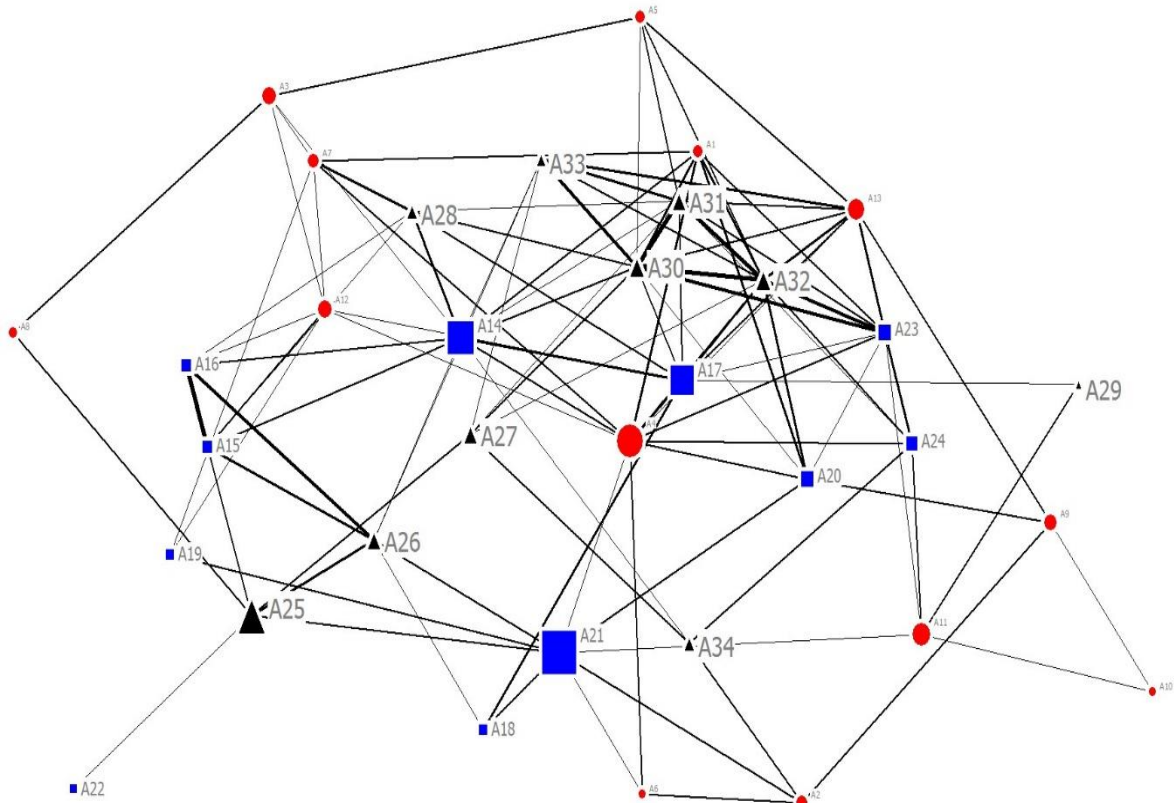
310           Figure 1 also shows that A30, A32, A31, A17, A14, A4, and A23 have the greatest degree  
311           centrality, whereby these variables are assumed to be linked with most of the other legal  
312           aspects. Based on the dimensions of the individual legal aspects, the degree centrality measures  
313           the legal aspects that have many ties to other aspects. In terms of contract structure, the aspect  
314           which has a high degree centrality include BIM data should be included as part of the contract  
315           (A4). For contractual responsibilities, a new BIM manager (A14), and the definition and the  
316           interrelationship among project participants involved in BIM are also had a high degree  
317           centrality. Additionally, the parties who use or contribute to the BIM model, and who should  
318           also apply the standard of care when handling the model (A23), is another influential legal  
319           aspect. For the BIM model and security, the impactful aspects include the security of digital  
320           data usage and the protection of integrity (A30), certain control mechanisms should be adopted  
321           to mitigate the loss of data and privacy (A31) and data providers should be responsible for the  
322           data provided by them in the BIM model (A32). Although the centrality degree measure  
323           captures the number of “interactions,” it does not, however, capture the capability of their  
324           “neighbors.” Hence, other measures are necessary to identify the dependency and the impacts  
325           of legal aspects on others.

326

327           4.3       Betweenness Centrality

328           Betweenness centrality describes the legal aspects that are important to the carrying of  
329           information between variables. By comparing with Fig.2 and Table IV, A14, A21, and A25  
330           have a high betweenness centrality, indicating they should be considered as carrying the most  
331           critical information among all the legal aspects. Although A25 does not have high degree  
332           centrality, it has high betweenness centrality. It plays an important role in information  
333           dependency. Legal aspects with a high betweenness centrality are regarded as being influential

334 within the association network as once they are removed from the network (broker and  
335 coordinator), they will disrupt connections between other legal aspects because they lie on the  
336 largest number of paths taken by messages. In terms of contract structure and policy, digital  
337 data should form part of the contract document (A4), the development of guidelines should  
338 follow the BIM model development (A11), and the cost of model development such as penalty  
339 and rewards should be clarified in the contract (A13). For contractual relationships and  
340 obligations, the significant legal aspects which are a new role of BIM manager should be  
341 appointed (A14), and the relationships between the project participants should be defined  
342 (A17). When devising the contracts, the issues pertaining to the designers should be responsible  
343 for the third party's negligence regardless of the privity of contracts (A21). The absence of this  
344 legal aspect will reduce the confidence level of using BIM and develop ambiguity among  
345 contracting parties regarding the responsibilities involved. The legal aspects of the BIM model  
346 and security have a lower betweenness centrality value relative to the two legal aspects but  
347 they are still considered important as in the absence of these aspects as they will de-facilitate  
348 the smooth implementation of BIM. These aspects, including the QR-code, should be used to  
349 prevent infringements (A25), while the designers own the copyright model (A27), the security  
350 of digital data should be protected (A27), and the data providers should be responsible for the  
351 data provided to them in the BIM model (A32).



352

353

Fig. 2 Association network visualized with betweenness centrality

354

355

Table V All of the most critical links are related to the highlighted nodes

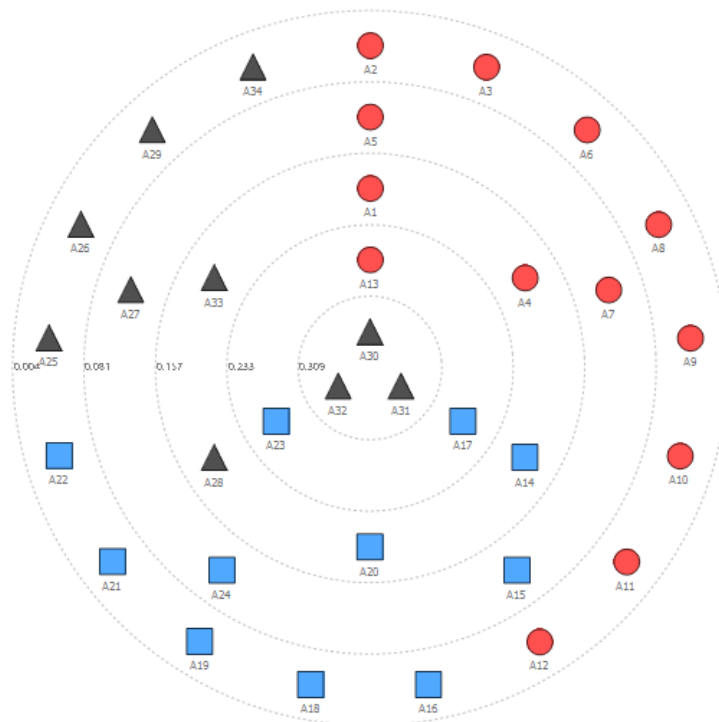
| Rank | Node | Bet. Centrality | Link    | Bet. Centrality |
|------|------|-----------------|---------|-----------------|
| 1    | A21  | 0.15            | A21-A25 | 40.78           |
| 2    | A25  | 0.11            | A22-A25 | 33.00           |
| 3    | A14  | 0.11            | A11-A21 | 32.21           |
| 4    | A4   | 0.11            | A25-A27 | 26.53           |
| 5    | A17  | 0.09            | A9-A13  | 23.99           |
| 6    | A11  | 0.06            | A17-A29 | 23.97           |
| 7    | A13  | 0.05            | A10-A11 | 21.78           |
| 8    | A30  | 0.04            | A8-A25  | 21.24           |
| 9    | A32  | 0.04            | A14-A34 | 20.84           |

356

## 357 4.4 Eigenvector Centrality

358 Eigenvector centrality is used to determine the most influential legal clauses in terms  
 359 of their power by considering the power of their neighbors. The most central actors can be  
 360 determined (i.e. those which are the least far removed from the others) in terms of the “global”  
 361 or “overall” structure of the network. In Fig. 3, the A30, A31, A32, A17, and A23 variables  
 362 have a high eigenvector centrality, indicating that these legal aspects are more peripheral. They  
 363 also connect to most of the aspects, which have a higher degree centrality. These aspects  
 364 include the protection of the security of digital data (A30), the implementation of certain  
 365 restrictions to reduce data loss (A31), and data providers being responsible for incorporating  
 366 the data into the BIM model (A32).

367



368

369

Fig. 3 Eigenvector centrality

370

371 5. Discussion and conclusions

372 The present study successfully utilized SNA to identify those influential legal aspects  
373 which will be used or modified as contract provisions in BIM contracts. The association  
374 network is developed and observed in terms of its structure as well as the status of each legal  
375 aspect. From a network perspective, the relationships among the three different legal aspects  
376 are rather dense and cohesive. The variables affecting data security have a higher degree of  
377 centrality, betweenness centrality, and eigenvector centrality. For instance, data should be  
378 protected (A30) and data providers should be liable for the inserted data (A32). In addition,  
379 the relationships among various stakeholders, their responsibilities, and punitive measures  
380 should be considered accordingly. For example, a BIM manager's role and the protection of  
381 intellectual property are critical "hinges," which interconnect various legal aspects.

382 In addition, some legal issues and requirements should be further considered when  
383 drafting BIM contracts. For instance, copyright issues are critical to maintaining the confidence  
384 of the designers, while maintaining the high-quality data entered as part of the process  
385 (Manderson et al., 2015), including confidential information about trade secrets and intellectual  
386 property allocation in a collaborative environment (Azhar, Khalfan, and Masqsood, 2012;  
387 Olsen and Taylor, 2010; Porwal and Hewage, 2013). Nevertheless, we found that this legal  
388 aspect remains critical in terms of the "hinges," which should be considered to protect data  
389 security. In other words, this study casts light on how these legal aspects interconnect with  
390 each other. Given that BIM-enabled projects may evolve and impose a legal liability on  
391 construction professionals, professional liability should be considered as a supporting  
392 mechanism that enables the operability of a contract (Khosrowshahi and Arayici, 2012; Olsen  
393 and Taylor, 2010; Rezgui et al., 2013). In the present study, the A34 variable (namely,  
394 indemnity being required to protect the client's interests in the event of any errors or technical  
395 issues caused by tools or software used in the project) addresses this topic, however, it does



396 not seem “critical” to the development of the contract. The reader should interpret this result  
397 carefully. Although the research has identified the “centrality” of legal aspects, those legal  
398 aspects that are non-central are not necessarily unimportant. Instead, these non-central legal  
399 aspects can serve as mechanisms that support the design of central legal aspects.

400 In conclusion, the present study has revealed insightful implications into significant legal  
401 aspects or contract provisions that need to be included in BIM contracts. These contribute to  
402 innovative contracts through the realization of the current strict and rigid contractual  
403 governance from conventional transaction cost economics theory. New adjustments to the  
404 contract functions can be considered, in which the coordination and contingency adaptability  
405 should be incorporated into the latent contract provisions, which will enhance the collaboration  
406 and relationships of the contracting parties in BIM-enabled projects. Consequently, this  
407 contracting approach can drive and improve the overall project performance. However, certain  
408 limitations must be considered. The application of legal doctrines such as the *Spearin* doctrine  
409 may not apply in Commonwealth countries. The research findings were based on Taiwanese  
410 legal formations. Hence, certain adjustments are required to enable application in countries  
411 with legal doctrines that differ from that in Taiwan. Moreover, different procurement strategies  
412 such as collaboration project delivery methods shall be distinguished from conventional  
413 procurement methods like design-bid-build and design-and-build when designing BIM  
414 contracts.

415

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421 **References**

- 422 AEC (2012). *AEC (UK) BIM PROTOCOL*. AEC (UK) CAD & BIM Standards Site, UK.  
423 Available at: <https://aecuk.files.wordpress.com/2012/09/aecukbimprotocol-v2-0.pdf>  
424 [3rd January 2018]
- 425 AIA (2013). *AIA Document E203TM-2013*. The American Institute of Architects, USA.  
426 Available at: <http://www.aia.org/aiaucmp/groups/aia/documents/pdf/aiab099084.pdf>  
427 [3rd January 2018]
- 428 Al-Shammari, M.A. (2014). “An appraisal of the protocol that was published by the  
429 construction industry council (CIC) to facilitate the use of building information  
430 modelling (BIM) on projects.” *Procs 30th Annual ARCOM Conference*, Association of  
431 Researchers in Construction Management, pp.623-632.
- 432 Arensman, D. B. and Ozbek, M. E. (2012). “Building information modeling and potential legal  
433 issues.” *International Journal of Construction Education and Research*, Vol. 8, No. 2, pp.  
434 146-156, DOI: 10.1080/15578771.2011.617808
- 435 Barthet, A. (2010). *A Contractor’s Defense: The Spearin Doctrine*. Available at:  
436 <http://www.thelienzone.com/a-contractors-defense-the-spearin-doctrine/> [3rd January  
437 2018]
- 438 BuildingSMART-Australasia 2012. *Strategy: A strategy for the focused adoption of building  
439 information modelling and related digital technologies and processes for the Australian  
440 built environment sector*. National Building Information Modelling Initiative. Vol.1
- 441 Buzan, T. and Buzan, B. (1996). *The Mind Map Book: How to Use Radiant Thinking to  
442 Maximize Your Brain's Untapped Potential*. Plume, USA.
- 443 CIC (2013). *CIC BIM Protocol*. Construction Industry Council, United Kingdom. Available  
444 at: <http://cic.org.uk/download.php?f=the-bim-protocol.pdf> [3rd January 2018]

445 Chew, A., and Riley, M. (2013). "What is Going On with BIM? The Way to 6D." *The*  
446 *International Construction Law Review*, pp.253-265.

447 Chong HY, Lopez R, Wang J, Wang X and Zhao Z. A. (2016). "Comparative Analysis on the  
448 Adoption and Use of BIM in Road Infrastructure Projects." *Journal of Management in*  
449 *Engineering*. DOI: 10.1061/(ASCE)ME.1943-5479.0000460.

450 Chong, H. Y., Fan, S. L., Sutrisna, M., Hsieh, S. H. and Tsai, C. M. (2017). "Preliminary  
451 Contractual Framework for BIM-Enabled Projects." *Journal of Construction Engineering*  
452 *and Management*, 143(7), pp. 1-8.

453 Chowdhury, A.N., Chen, P.H. and Tiong, R.L. (2011). "Analysing the structure of public–  
454 private partnership projects using network theory." *Construction Management and*  
455 *Economics*, Vol. 29, No.3, pp.247-260.

456 Chien, K. F., Wu, Z. H. and Huang, S. C. 2014. "Identifying and assessing critical risk factors  
457 for BIM projects: Empirical study." *Automation in Construction*, Vol. 45, pp. 1-15.

458 ConsensusDocs (2013). ConsensusDocs 301: Building Information Modelling (BIM)  
459 Addendum. ConsensusDocs, US.

460 CPC (2013). Contract for Complex Projects. The Chartered Institute of Building, United  
461 Kingdom. Available at: [http://www.ciob.org/media-centre/news/world%e2%80%99s-](http://www.ciob.org/media-centre/news/world%e2%80%99s-first-time-management-contract-complex-projects-published-ciob)  
462 [first-time-management-contract-complex-projects-published-ciob](http://www.ciob.org/media-centre/news/world%e2%80%99s-first-time-management-contract-complex-projects-published-ciob) [3rd January 2018].

463 Doloi, H. (2012). "Assessing stakeholders' influence on social performance of infrastructure  
464 projects." *Facilities*, Vol. 30, No.11/12, pp.531-550.

465 Eadie, R., McLernon, T. and Patton, A. (2015). "An investigation into the legal issues relating  
466 to Building Information Modelling (BIM)." *Proceedings of RICS COBRA AUBEA 2015*.

467 Enegbuma, W. I. and Ali, K. N. (2011). "A Preliminary Study on Building Information  
468 Modeling (BIM) Implementation in Malaysia." *3rd International Postgraduate*  
469 *Conference on Infrastructure and Environment (IPCIE2011), Hong Kong*.

470 Estrada, E. and Rodriguez-Velazquez, J.A. (2005). "Subgraph centrality in complex networks."  
471 *Phys. Review*, Vol.71, No. 5, 056103.

472 Fan, S.L. (2014). "Intellectual Property Rights in Building Information Modelling application  
473 in Taiwan." *Journal of Construction Engineering Management*, Vol. 43, No. 3. DOI:  
474 10.1061/(ASCE)CO.1943-7862.0000808

475 Greenwood, D., Lewis, S. and Lockley, S., (2010). "Contractual Issues in the Total Use of  
476 Building Information Modelling." *Proceeding: W113 - Special Track 18th CIB World  
477 Building Congress May 2010 Salford, UK*, pp. 363-371.

478 Guo, L., Vu, H. T. and McCombs, M. (2012).  
479 "An Expanded Perspective on Agenda-Setting Effects. Exploring the third level of  
480 agenda setting." *Revista de Comunicación*, Vol.11, pp.51-68.

481 Hardin, B. and McCool, D. 2015. *BIM and construction management: proven tools, methods,  
482 and workflows*. John Wiley & Sons.

483 Hsieh, T.Y., Yeh, F. and Hsu, K.M. (2012). "Legal Risks Incurred under the Application of BIM  
484 in Taiwan." *14th International Conference on Computing in Civil and Building  
485 Engineering*, Mscow, Russia.

486 Hsu, K. M., Hsieh, T. Y. and Chen, J. H. 2015. Legal risks incurred under the application of  
487 BIM in Taiwan. *Proceedings of the Institution of Civil Engineers-Forensic  
488 Engineering*, Vol. 168, No. 3, pp.127-133.

489 JCT (2011). Public Sector Supplement: Fair Payment, Transparency and Building Information  
490 Modelling. Available at: [http://corporate.jctltd.co.uk/wp-content/uploads/2016/03/JCT-  
491 Public-Sector-Supplement-Dec20111.pdf](http://corporate.jctltd.co.uk/wp-content/uploads/2016/03/JCT-Public-Sector-Supplement-Dec20111.pdf) □3rd January 2018□

492 Joyce, R. and Houghton, D. 2014. Briefing: Building Information Modelling and the Law.  
493 *Proceedings of the Institution of Civil Engineers Management, Procurement and Law*,  
494 Vol.167, No. 3, pp.114–116.

495 Kuiper, I. and Holzer, D. (2013). "Rethinking the contractual context for Building Information  
496 Modelling (BIM) in the Australian built environment industry." *Australasian Journal of*  
497 *Construction Economics and Building*, Vol 13, No. 4, pp.1-17.

498 Lee, C. Y., Chong, H. Y., Liao, P. C. and Wang, X. (2018). Critical Review of Social Network  
499 Analysis Applications in Complex Project Management. *Journal of Management in*  
500 *Engineering*, Vol. 34, No. 2, 04017061.

501 Lorenzo, T. M., Benedetta, B., Manuele, C. and Davide, T. 2014. "BIM and QR-code. A  
502 synergic application in construction site management." *Procedia Engineering*, Vol.85, pp.  
503 520-528.

504 Lowe, R. H. and Muncey, J. M. (2009). "The ConsensusDOCS 301 BIM Addendum."  
505 *Construction Lawyer*, Vol.29, No.1, pp.1-9.

506 Lowry, D.T., Nio, T.C.J. and Leitner, D.W., 2003. "Setting the public fear agenda: A  
507 longitudinal analysis of network TV crime reporting, public perceptions of crime, and  
508 FBI crime statistics." *Journal of Communication*, Vol. 53, No. 1, pp.61-73.

509 Mahamadu, A.M., Mahdjoubi, L. and Booth, C. (2013). "Challenges to BIM-cloud integration:  
510 Implication of security issues on secure collaboration." *IEEE International Conference*  
511 *on Cloud Computing Technology and Science*, pp.209-214.

512 McAdam, B. (2010). "Building information modelling: the UK legal context." *International*  
513 *Journal of Law in the Built Environment*, Vol.2, No. 3, pp. 246 - 259.

514 McCombs, M. and Reynolds, A (2002). News Influence on Our Pictures of the World. In J.  
515 Bryant, & D. Zillmann (Eds.), *Media Effects: Advances in Theory and Research* (2nd ed.,  
516 pp. 1-18). Mahwah: LEA.

517 Meijer, M. M. and Kleinnijenhuis, J. (2006). "Issue news and corporate reputation: Applying  
518 the theories of agenda setting and issue ownership in the field of business  
519 communication." *Journal of Communication*, Vol. 56, No. 3, pp.543-559.

520 Olatunji, O.A. (2011). A Preliminary Review on the Legal Implications of BIM and Model  
521 Ownership. *Journal of Information Technology in Construction*. Vol. 16, pp. 687-696.

522 Pishdad-Bozorgi, P., Austin, R.B. and de la Garza, J.M. (2016). “Network Analysis of Flash-  
523 Track Practices.” *Journal of Management in Engineering*, p.04016024.

524 Redmond, A., Hore, A. V. and West, R. (2010). “Developing a cloud integrated life cycle  
525 costing analysis model through BIM.” *CIB W78 2011: Computer Knowledge Building*,  
526 *Sophia Antipolis – France*.

527 Simonian, L. and Korman, T., (2010). “Legal Considerations in the United States Associated  
528 with Building Information Modeling.” *The Construction, Building and Real Estate*  
529 *Research Conference of the Royal Institution of Chartered Surveyors, RICS COBRA2010*.

530 Smith, P. (2014). “BIM Implementation-Global Strategies.” *Creative Construction*  
531 *Conference, CC2014. Procedia Engineering*. Vol. 85, pp. 482-492.

532 Solis, F., Sinfield, J.V. and Abraham, D.M. (2013). “Hybrid approach to the study of inter-  
533 organization high performance teams.” *Journal of Construction Engineering and*  
534 *Management*, Vol.139, No. 4, pp.379-392.

535 Steel, J., Drogemuller, R. and Toth, B. (2012). “Model interoperability in building information  
536 modelling.” *Software & Systems Modeling*, Vol.11, No.1, pp.99-109.

537 Ussing, L. F., Svidt, K. and Wandahl, S. (2016). “Legal Aspects Connected to the Use of BIM  
538 in the Danish Building Sector.” *Construction Research Congress 2016, ASCE*, pp. 528-  
539 537.

540 Vu, H. N. N. and Gehrau, V. (2010). “Agenda diffusion: An integrated model of agenda setting  
541 and interpersonal communication.” *Journalism & Mass Communication Quarterly*, Vol.  
542 87, No. 1, pp.100-116.

543 Wambeke, B.W., Liu, M. and Hsiang, S.M. (2014). “Task variation and the social network of  
544 construction trades.” *Journal of Management in Engineering*, Vol. 30, No.4, 05014008.