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

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

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Abstract

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

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

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

1. Introduction

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

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

2. Legal Aspects and Contract Provisions

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

2.1 Contract structure and policy

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

2.2 Contractual relationships and obligations

The development of a BIM model is a joint effort by several parties. In a common practice, a BIM execution plan will explain the details of the necessary checklist and standards for the project implementation. Unfortunately, this document generally does not form part of the contract (Hardin and McCool, 2015). The unclear roles and responsibilities give rise to legal liabilities (McAdam, 2010), including pure economic loss (Simonian and Korman, 2010). Hence, the contractual relationships need to be clarified especially for the key stakeholders (including the BIM manager), which will help to regulate the required responsibilities or functions in the BIM Execution Plan (Lowe and Muncey, 2009). This situation could then trigger another legal question on the need for additional insurance coverage throughout the development of BIM model (Enegbuma and Ali, 2011).

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

2.3 BIM model and security

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

Apart from that, a third party may incur an infringement claim from the model. It is advised that to make clear the intellectual property rights at the outset of the model development. The available BIM contract protocols such as ConsensusDOCS 301 BIM Addendum and AIA Document E202 envisage that each party should own his/her rights as per the personal contribution. It also needs to comply with local statutory law or regulations in relation to data privacy and security (Fan, 2014). Therefore, all digital data should be well-kept and controlled. In addition, indemnity should be provided to protect the client's interests in the BIM model.

3. Research Methodology

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

3.1 Identification of legal aspects

We relied on the existing measurement scales of the key legal aspects for the questionnaire design, for which the legal aspects have been validated in prior research (Chong et al., 2017). The questionnaire was organized into two sections, namely, Section A which was used to investigate the background of the respondents, and Section B which was used to examine the levels of agreement on the identified thirty-four legal aspects (A1 to A34) and the appropriateness of the legal aspects of BIM contracts. The measurement items A1, A2, A3, A4, A15, and A16 were excluded in the questions pertaining to the appropriateness of the legal aspects of BIM contracts as these were the legal issues associated with BIM contracts. The five-point Likert scale, ranging from 1 (representing a zero of the trait; e.g. strongly disagree) to 5 (representing a perfectly positive assessment of the trait; e.g., strongly agree) was conducted by representing the points in weighting with values of -2, -1, 0, 1, and 2 respectively in the analysis. Table I lists the measurement items of the legal aspects (Chong et al., 2017).

Table I Key legal aspects for BIM-enabled projects

Code	**Legal Aspects**
Aspect #1	**Contract Structure and Policy**
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	**<u>Contractual Relationships and Obligations</u>**
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.

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

3.2 Development of association matrix

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

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

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

where cov represents the covariance and σ_{v_i} stands for the deviation in v_i.

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

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

3.3 Visualization of association network

3.3.1 Network index

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

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

Cohesion: Cohesion (G) refers to the condensed value of network G, as given by Eq. 3. AdjM is the adjacency matrix of network G. Z represents the average shortest-path between points. AdjM2 is the number of connecting lines while Z is in the network. N is the total number of variable items. As the cohesion increases, so too does the complexity of the variable relationship.

$$\text{Cohesion}（G）= (\sum \text{AdjMz}) / (N(N-1) \tag{3}$$

3.3.2 Point/line index

Degree Centrality: This refers to the number of edges directly attached to a node. It is used to analyze the importance of a node from its leadership and influence positions within a network (Doloi, 2012). Nevertheless, degree centrality may not necessarily be a proxy for a node's leadership position (Solis et al., 2013). Hence, other measures must be used to determine the importance and the saliency of the legal aspects. Degree centrality is expressed as in Eq. (4):

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

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

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

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

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

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

Coordinator: If a variable v_i is correlated with another two variables v_j and v_k in the same partition, then add one coordinator score to variable v_i. If either one of the v_j and v_k is associated with v_i, add one gatekeeper or representative score to v_i. In both v_j and v_k are in the same partition but different from v_i, and both are associated with v_i, then add 1 itinerant 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.

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

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

where M (v) is a set of neighbors of v and λ is a constant.

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

4. Results and Analysis

Thirty-six valid questionnaires were returned and used for the data analysis. This sample size is sufficient when applying the central limit theorem based on its means value that approaches the normal distribution. Table II shows that most of the respondents were aged from within 41 to 60 (56%); some were below 40 (36%), and few were above 60 (8%). Their occupations included architects (33%), consultants (28%), contractors (22%), educators (17%), developers (3%), and government employers (3%). Most of the respondents had attained a post-graduate level of education (61%) and had more than ten years working experience in the construction industry (67%).

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

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

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

4.1 Network structure

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

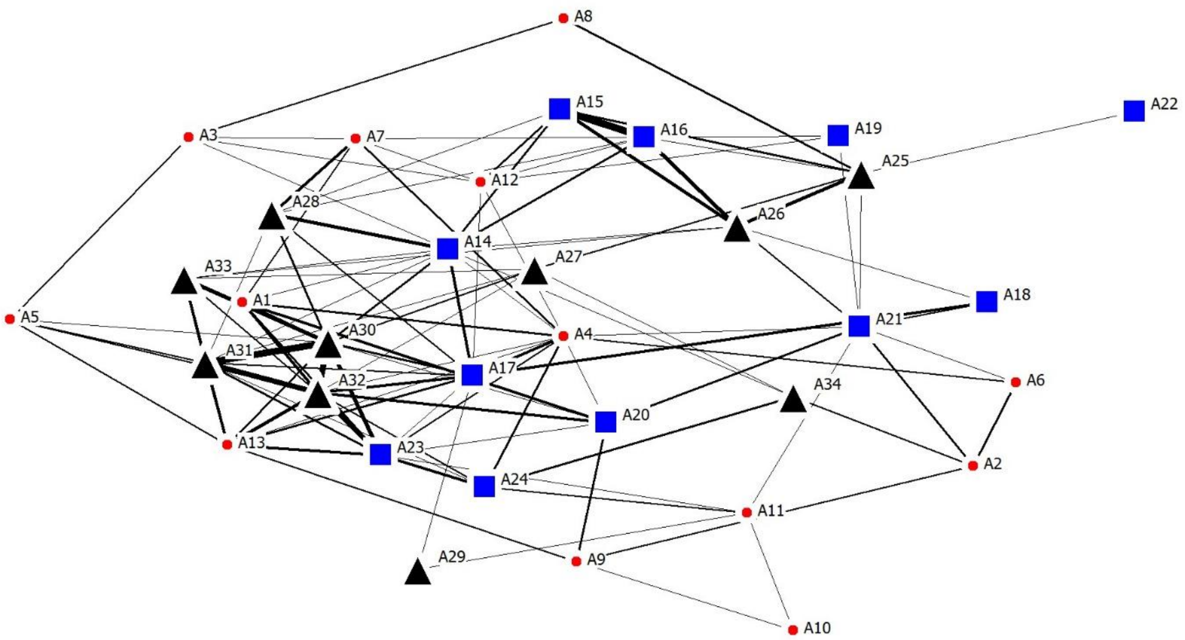

Fig.1: Association network visualized with degree centrality

Table IV Summary of Network Metrics

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

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

4.2 Degree Centrality

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

4.3 Betweenness Centrality

Betweenness centrality describes the legal aspects that are important to the carrying of information between variables. By comparing with Fig.2 and Table IV, A14, A21, and A25 have a high betweenness centrality, indicating they should be considered as carrying the most critical information among all the legal aspects. Although A25 does not have high degree centrality, it has high betweenness centrality. It plays an important role in information dependency. Legal aspects with a high betweenness centrality are regarded as being influential within the association network as once they are removed from the network (broker and coordinator), they will disrupt connections between other legal aspects because they lie on the largest number of paths taken by messages. In terms of contract structure and policy, digital data should form part of the contract document (A4), the development of guidelines should follow the BIM model development (A11), and the cost of model development such as penalty and rewards should be clarified in the contract (A13). For contractual relationships and obligations, the significant legal aspects which are a new role of BIM manager should be appointed (A14), and the relationships between the project participants should be defined (A17). When devising the contracts, the issues pertaining to the designers should be responsible for the third party's negligence regardless of the privity of contracts (A21). The absence of this legal aspect will reduce the confidence level of using BIM and develop ambiguity among contracting parties regarding the responsibilities involved. The legal aspects of the BIM model and security have a lower betweenness centrality value relative to the two legal aspects but they are still considered important as in the absence of these aspects as they will de-facilitate the smooth implementation of BIM. These aspects, including the QR-code, should be used to prevent infringements (A25), while the designers own the copyright model (A27), the security of digital data should be protected (A27), and the data providers should be responsible for the data provided to them in the BIM model (A32).

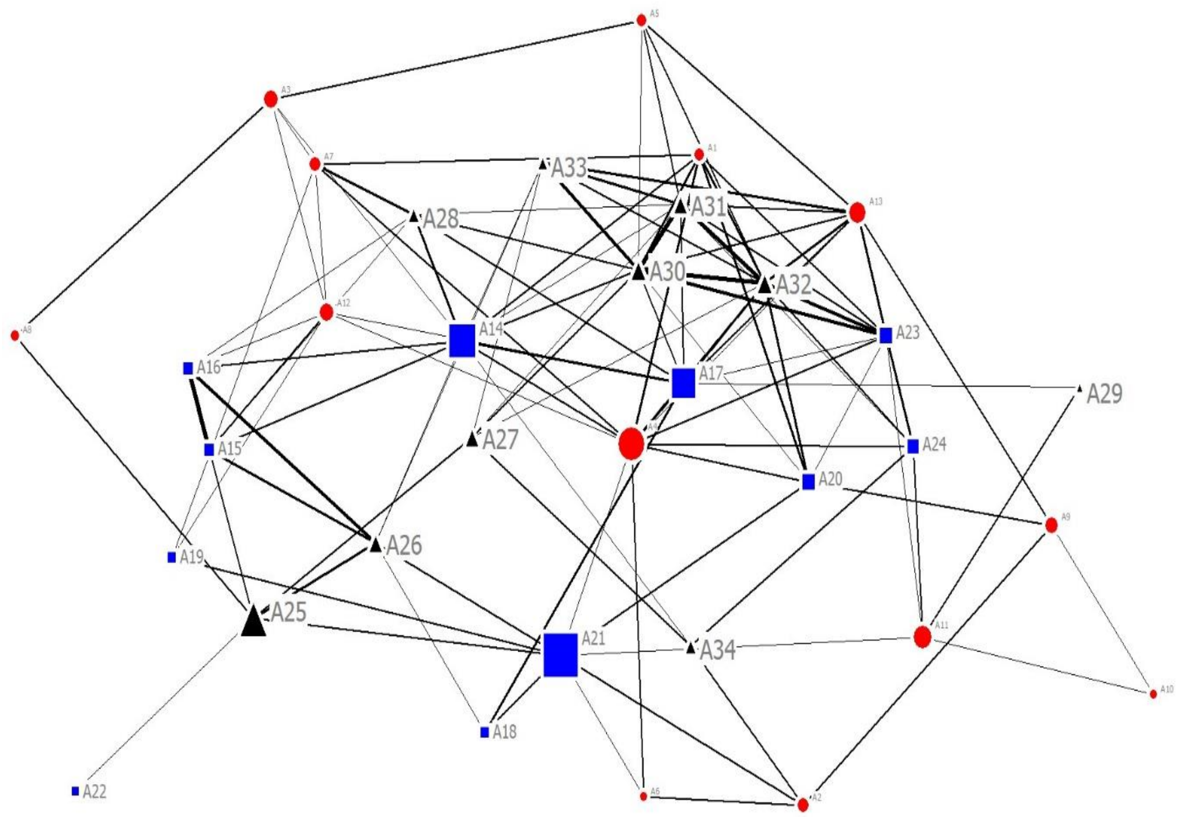

Fig. 2 Association network visualized with betweenness centrality

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

10	A27	0.04	A19-A21	20.41

4.4 Eigenvector Centrality

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

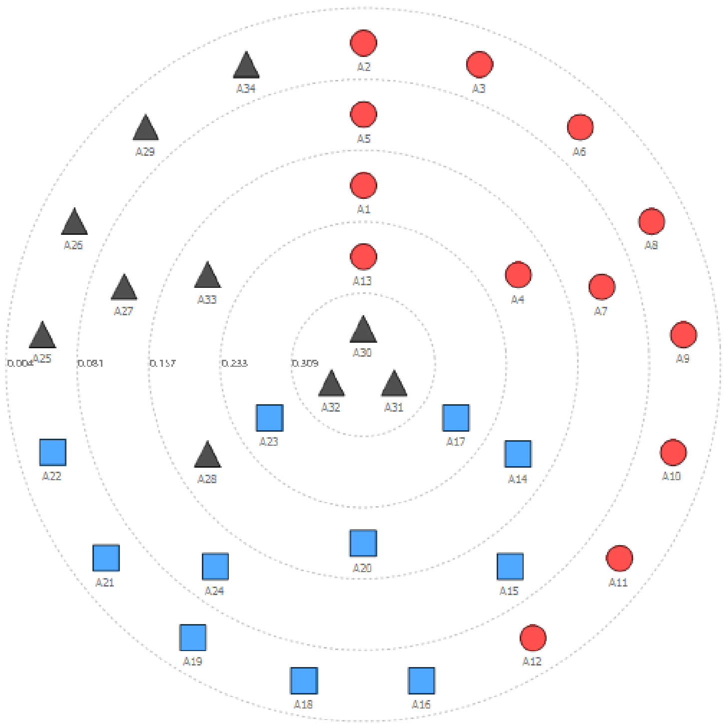

Fig. 3 Eigenvector centrality

5. Discussion and conclusions

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

In addition, some legal issues and requirements should be further considered when drafting BIM contracts. For instance, copyright issues are critical to maintaining the confidence of the designers, while maintaining the high-quality data entered as part of the process (Manderson et al., 2015), including confidential information about trade secrets and intellectual property allocation in a collaborative environment (Azhar, Khalfan, and Masqsood, 2012; Olsen and Taylor, 2010; Porwal and Hewage, 2013). Nevertheless, we found that this legal aspect remains critical in terms of the "hinges," which should be considered to protect data security. In other words, this study casts light on how these legal aspects interconnect with each other. Given that BIM-enabled projects may evolve and impose a legal liability on construction professionals, professional liability should be considered as a supporting mechanism that enables the operability of a contract (Khosrowshahi and Arayici, 2012; Olsen and Taylor, 2010; Rezgui et al., 2013). In the present study, the A34 variable (namely, indemnity being required to protect the client's interests in the event of any errors or technical issues caused by tools or software used in the project) addresses this topic, however, it does not seem “critical” to the development of the contract. The reader should interpret this result carefully. Although the research has identified the “centrality” of legal aspects, those legal aspects that are non-central are not necessarily unimportant. Instead, these non-central legal aspects can serve as mechanisms that support the design of central legal aspects.

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

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References

AEC (2012). *AEC (UK) BIM PROTOCOL*. AEC (UK) CAD & BIM Standards Site, UK. Available at: https://aecuk.files.wordpress.com/2012/09/aecukbimprotocol-v2-0.pdf [3rd January 2018]

AIA (2013). *AIA Document E203TM-2013*. The American Institute of Architects, USA. Available at: http://www.aia.org/aiaucmp/groups/aia/documents/pdf/aiab099084.pdf [3rd January 2018]

Al-Shammari, M.A. (2014). "An appraisal of the protocol that was published by the construction industry council (CIC) to facilitate the use of building information modelling (BIM) on projects." *Procs 30th Annual ARCOM Conference*, Association of Researchers in Construction Management, pp.623-632.

Arensman, D. B. and Ozbek, M. E. (2012). "Building information modeling and potential legal issues." *International Journal of Construction Education and Research*, Vol. *8*, No. 2, pp. 146-156, DOI: 10.1080/15578771.2011.617808

Barthet, A. (2010). *A Contractor's Defense: The Spearin Doctrine*. Available at: http://www.thelienzone.com/a-contractors-defense-the-spearin-doctrine/ [3rd January 2018]

BuildingSMART-Australasia 2012. *Strategy: A strategy for the focused adoption of building information modelling and related digital technologies and processes for the Australian built environment sector*. National Building Information Modelling Initiative. Vol.1

Buzan, T. and Buzan, B. (1996). *The Mind Map Book: How to Use Radiant Thinking to Maximize Your Brain's Untapped Potential*. Plume, USA.

CIC (2013). *CIC BIM Protocol*. Construction Industry Council, United Kingdom. Available at: http://cic.org.uk/download.php?f=the-bim-protocol.pdf [3rd January 2018]

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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