Preliminary Contractual Framework for BIM-Enabled Projects

Heap-Yih Chong[1]; Su-Ling Fan[2]; Monty Sutrisna[3]; Shang-Hsien Hsieh[4]; and Ching-Mei Tsai[5]

Abstract: Building information modeling (BIM) has entered into another phase of maturity, especially in countries that have been actively adopting and using BIM including in Taiwan, Republic of China. An effective management in BIM has increasingly become one of the demanding features in Taiwanese architecture, engineering, construction, and operation industries, particularly in dealing with the legal issues associated with BIM implementation. Therefore, the research aims to develop a preliminary contractual framework for BIM-based contract administration. Two objectives underpin the research, namely, (1) to identify the potential legal aspects that need to be considered in BIM-enabled projects, and (2) to determine the related contract provisions required in BIM contracts. The questionnaire survey method was adopted through a selective sampling approach in Taiwan. Thirty-six valid and completed questionnaires were analyzed. The results identify 21 related contract provisions that could potentially be used in BIM contracts. Following a thorough analytical discussion, these contract provisions were then incorporated into the developed contractual framework. While paving the way for a robust contractual mechanism for BIM-enabled projects in the future, the research contributes to the body of knowledge for BIM-based contract administration.
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Introduction

From the international perspective, various building information modeling (BIM) contract protocols have been established for administrating contracts. For example, the American Institute of Architects (AIA) has published Document E203—2013 (AIA 2013), and ConsensusDocs has published its 301 Building Information Modeling Addendum (ConsensusDocs 2013). Also, there are the AEC BIM Protocol (2012) and Construction Industry Council BIM Protocol (2013) in the United Kingdom. Building information modeling has also been incorporated and considered in the Contract for Complex Projects (Chartered Institute of Building 2013). However, the protocols only serve as a guideline in contract administration and appeared to provide an average performance in overcoming the legal issues associated with BIM implementation (Al-Shammari 2014). Moreover, many construction personnel are still unaware of the existence of BIM standard form documents or protocols (Rizer 2012). Thus, despite the fact that BIM itself is gaining momentum, the use of the standardized BIM protocols remains low.

Previous studies were mostly review papers, which were reviewing potential legal implications of BIM (Olatunji 2011), BIM's legal issues and considerations in contract (Joyce and Houghton 2014), contractual arrangements for BIM in Australia (Kuiper and Holzer 2013), and BIM's legal risks in Taiwan (Hsu et al. 2015). Some preliminary empirical studies were also conducted such as qualitative analyses from interviews on potential legal issues in BIM (Arensman and Ozbek 2012) and intellectual property rights for BIM's copyright and ownership (Fan 2014). A questionnaire survey was also conducted in United Kingdom for a preliminary investigation on the significant legal issues stifling BIM implementation (Eadie et al. 2015). From these, it can be concluded that the related works on BIM and legal issues were still at an exploratory stage due to limited empirical data across the architectural, engineering, construction, and facility management and operation (AECO) industries. Thus there is a need for a comprehensive study to address the potential legal issues, especially from the contract administration perspective.

Therefore, the research aims to develop a preliminary contractual framework for BIM-based contract administration. The research is underpinned with two objectives: (1) to identify potential legal aspects generally required in BIM-enabled projects; and (2) to determine the related contract provisions required in BIM contracts. A questionnaire survey was utilized to obtain the empirical data of the potential legal aspects and contract provisions. The scope of this research focuses on a country that has actively adopted and used BIM, namely, Taiwan, Republic of China, due to the proactive implementation of BIM to the level of its local governments in their public projects (Chien et al. 2014). The proposed contractual framework will provide a contemporary analysis on the potential legal aspects and contract provisions that are practical and feasible for future uses in BIM-based contract administration.

[1]Senior Lecturer, School of Built Environment, Curtin Univ., GPO Box U1987, Perth, WA 6845, Australia. E-mail: heapyih.chong@curtin.edu.au

[2]Director, Research Development Center of Construction Law, Tamkang Univ., No. 151, Yingzhuan Rd., Tamsui Dist., New Taipei City, Taiwan 25137, Republic of China; Associate Professor, Dept. of Civil Engineering, Tamkang Univ., No. 151, Yingzhuan Rd., Tamsui Dist., New Taipei City, Taiwan 25137, Republic of China (corresponding author). E-mail: fansuling@hotmail.com

[3]Associate Professor, School of Built Environment, Curtin Univ., GPO Box U1987, Perth, WA 6845, Australia. E-mail: monty.sutrisna@curtin.edu.au

[4]Professor, Dept. of Civil Engineering, National Taiwan Univ., Taipei City, Taiwan 10617. E-mail: shhsieh@ntu.edu.tw

[5]Postgraduate Student, Dept. of Civil Engineering, Tamkang Univ., No. 151, Ying-Chuan Rd., Tamsui, Taipei County 251, Taiwan. E-mail: careytsai@teco.com.tw

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Legal Aspects Associated with BIM Implementation

Various legal issues have been forecasted in BIM-enabled projects in the AECO industries. This section of the paper intends to elaborate and organize the legal issues and questions raised from the related literature, which were then included in a questionnaire survey to identify potential legal aspects that could be considered as contract provisions in future BIM contracts. Following a thorough literature review, the legal aspects have been categorized into three classifications, namely, (1) contract structure and policy, (2) contractual relationships and obligations, and (3) BIM model and security.

Contract Structure and Policy

The traditional legal frameworks have been designed to govern fragmented practices and conventions in construction projects (Chong and Phuah 2013). However, BIM enables and promotes a collaborative working platform for all project stakeholders. The existing BIM contract protocols are mainly used as supporting documents, yet they are generally used as an addendum to the original contract. There is still a lack of clarity over the changing roles and legal responsibilities required for BIM's project requirements (Redmond et al. 2010). This creates the need for an alternative contract structure to accommodate the construction procurement (O'Connor et al. 2016) and contracting methodologies including progress payments (Kuiper and Holzer 2013) and project financing options (Lu et al. 2016). The integrated project delivery (IPD) procurement system has been proposed associated with BIM implementation. Building SMART-Australasia (2012) contends that standard contracts need to be developed for this procurement system. Yet, IPD might not offer the sole solution for the procurement system (Holzer 2007). Integrated project delivery contracts are generally drafted on an ad hoc basis, which will inhibit their widespread uses in the industry (Smith 2014). The complexity of the IPD system has also been perceived to cause slow adoption, hence its unpopularity in BIM-enabled projects.

As a result, some potential legal aspects can be initiated to address these legal issues, or can be predicted to accommodate unknown situations associated with BIM implementation. These aspects will formulate the fundamental principles in the contract as shown in Table 1.

Contractual Relationships and Obligations

All project stakeholders work collaboratively in BIM-enabled projects. The BIM execution plan will be developed to provide the necessary checklist and guidance for the successful BIM implementation. Although this document is generally not a part of the contract (Hardin and McCool 2015), the stakeholders' roles and project scopes need to be well defined and governed. If there are no contractual relationships, their participation may not give rise to legal liability (McAdam 2010), including pure economic loss (Simonian and Korman 2010). Hence, the clear contractual relationships of the key stakeholders (including BIM manager) will help to regulate the required responsibilities or functions in the BIM execution plan (Lowe and Muncey 2009). This situation also raises another legal questions on the need for additional insurance, particularly for the design liability on the BIM model (Enegbuma and Ali 2011).

In addition, when certain liabilities or obligations have been identified and made clear in the contract, the standard of care should be the next matter that needs to be clarified. Privity of contract and the Spearin doctrine should be onsidered. For example, the use of a collaborative system should reduce the likelihood of a designer claiming the lack of privity of contract in a legal defense (Simonian and Korman 2010). As for the Spearin doctrine, it can be used by contractors as a defense to an owner's claim of defective and nonconforming work (Barthet 2010).

Following the review, Table 2 shows the potential legal aspects that can be considered for the contractual relationships and obligations associated with BIM implementation.

BIM Model and Security

Security and privacy issues will likely impede widespread adoption of BIM (Mahamadu et al. 2013). The BIM's information is digitized and parameterized, which means the information can be easily extracted and reused in whole or in part (Fan 2014). Therefore, it raises a new problem about how the business knowledge can be protected. 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 considered for prevention of any infringements or copyrights issues on the drawings and documents in the BIM-enabled projects. A data management policy is needed for all project development stages to avoid exchanging the unnecessary and incorrect information in BIM-enabled projects (Greenwood et al. 2010). The data management policy should also address common interoperability issues from different softwares (Lopez et al. 2015), although the Industry Foundation Classes (IFC) data modeling format has been referred to and used in the model development (Steel et al. 2012).

Table 1. Potential Legal Aspects for Contract Structure and Policy

Variables of legal aspects	Descriptions
A1	Specific BIM standard form of contract is required to cover all scopes and project requirements; or
A2	Addendum is sufficient to cover a certain BIM's scopes and requirements.
A3	The BIM's scopes and requirements should not be enforced with legal implications; or
A4	Digital data or information should be treated as a part of the contract document.
A5	Two-dimensional (2D) drawings will prevail over three-dimensional drawings for any discrepancies in all circumstances; or
A6	Three-dimensional drawings will prevail over 2D drawings for any discrepancies from the fully developed or high level of detail BIM model.
A7, A8, A9, A10	The BIM's cost or payment should be charged according to (1) a fixed percentage of the overall project cost; (2) the types of development, models, and functions required for the project; (3) progress payment on the work done; or (4) completion of the models and functions required in the project.
A11	Established standards or guidelines should be applied or followed throughout BIM model development.
A12	Use of collaborative project delivery approach is needed in BIM-enabled projects, such as IPD and partnering.
A13	Cost for model development should be clarified including the penalty and rewards involved, if any.

Table 2. Potential Legal Aspects for Contractual Relationships and Obligations

Variables of legal aspects	Descriptions
A14	New BIM manager role should be engaged in the project.
A15	Contract should define the roles and scopes of works for all parties involved in the project.
A16	Contract should define the BIM's goals and quality checks for different stages of development.
A17	Relationship among the client, designers, and contractors should be clearly defined and connected in the project.
A18	Loss due to the negligence of the design team should be recovered by the injured party or third party; the design team is not responsible for it.
A19	Disclaimers are prohibited for excluding design responsibilities for the developed BIM model.
A20	Spearin doctrine should be applied and upheld, where the contractor will not be liable for the loss caused by the insufficient information the contractor received or followed solely for the project.
A21	Designers will be responsible for the negligence toward the third party regardless of privity of contract.
A22	Contractor cannot make a claim from the design errors by the designers including pure economic loss.
A23	Standard of care should be applied and upheld by all parties who contribute to or use the BIM model.
A24	Additional insurance coverages are required to insure all risks and liabilities involved in BIM models, software, and hardware.

Apart from that, the development of the BIM model can be seen as a joint effort by multiple parties. There is a possibility of an infringement claim from a third party. The intellectual property rights need to be defined at the early stage of project development. The available BIM contract protocols (e.g., ConsensusDOCS 301 BIM Addendum and AIA Document E202) suggest that each party owns all rights to its own contribution and also 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. The indemnity may be considered in the BIM model to protect the client's interest. Table 3 shows the potential legal aspects in governing the technical aspects of the BIM model and the related copyright and data management issues.

Methodology

BIM has not been mandated in Taiwan but many government sectors have proactively implemented and initiated BIM in their projects. Therefore, there is a very high degree of adoption and use rate of BIM in the AECO industries in Taiwan, which is suitable for a quantitative analysis like this, i.e., to capture a wide spectrum of responses on the matter. Hence, a structured questionnaire survey method was adopted to investigate and identify the potential legal aspects in BIM-enabled projects based on the 34 variables. Meanwhile, the same variables were surveyed to determine their appropriateness as contract provisions in BIM contracts excluding Variables A1, A2, A3, A4, A15, and A16, which were related to the legal aspects that must be considered or incorporated in BIM contracts.

Selective sampling was used in the questionnaire survey method in this exploratory study. Most of the BIM-enabled projects were initiated and funded by the local governments in Taiwan, so the contacts of the respondents were collected from organizations and/or individuals that had engaged works with the local authority. However, the practice of BIM is not yet fully mature, so the selective sampling technique has been conducted properly to include those respondents who have appropriate understanding and knowledge in BIM.

The questionnaire was organized into two sections, namely, Section A was asking for demographics of the respondents, whereas Section B was asking for the agreement on the potential legal aspects, and most of them require two answers. The first answer was to indicate the extent of agreement (on a scale of 1–5) with the potential legal aspects. The second answer was an indication of the appropriateness (on a scale of 1–5) of the legal aspects being incorporated as contract provisions into the BIM contracts. The means and standard deviation (SD) were analyzed based on the 5-point Likert scale.

The analysis of the questions involving the 5-point Likert scale (ranging from strongly disagree to strongly agree) was conducted by representing the points in weighting (w) with values of -2, -1, 0, 1, and 2, respectively. The mean ($\bar{x}$) of the number of samples (n) is then calculated as follows:

Table 3. Potential Legal Aspects for BIM Model and Security

Variables of legal aspects	Descriptions
A25	QR-Code should be adopted to prevent any infringements or copyrights issues on the drawings and documents.
A26	When avoiding interoperability issues, the development of the BIM model should work in advance in all project development stages, and produce a construction-ready BIM model before the construction stage.
A27	Designers who develop the model own the rights of copyright when the model is created.
A28	Owner of the model or the client can use, access, and reproduce the model if permission has been sought from the copyright owner.
A29	If the model is designed and contributed by a team, each party owns all rights to its own contribution.
A30	Digital data should be protected with security for its usage and data integrity.
A31	Certain constraints should be implemented to prevent data loss and privacy.
A32	Data providers (designers or contractors) should be responsible and liable for the inserted data in the model.
A33	The party who hosts the model should include the use and access, recordkeeping, and warranty, and preserve the model for the agreed duration.
A34	Indemnity is required to protect the client's interest for any errors or technical issues form tools or software in the project.

$$\bar{x} = \frac{\sum_{i=1}^{n} w_i}{n}$$

The means were then grouped into three simple categories for ease of analysis, especially when clarifying with complicated legal issues, namely:

- Agree = $0.50 \leq$ means ≤ 2.00;
- Undecided = $-0.50 \leq$ means < 0.50; and
- Disagree = $-2.00 \leq$ means < -0.50.

For instance, if the appropriateness variables fell within the range of the agree category, the variables could be then serve as the related contract provisions in BIM contracts.

Results and Analysis

Approximately 50 potential respondents were identified and asked to participate in the questionnaire survey; 36 valid questionnaires were responded to and collected. This sample size is sufficient by referring to central limit theorem, which is to approach the approximate normal sampling distribution for analyzing the means scores as required in the research (Serfling 2009). The majority of the respondents have received a postgraduate level of study (61%) and have had more than 10 years of experience working in the construction industry (67%). They are mainly working as contractors (22%), architects (33%), and consultants (28%). Meanwhile, the rest of the respondents are with academic institutions (11%), developers (3%), and the government sector (3%). The majority group (67%), or 24 respondents, have worked and been involved directly in BIM-enabled projects. Some respondents have not been directly involved in BIM-enabled projects, but they were filtered in the selective sampling process to identify those with a good understanding and knowledge in BIM, for instance, professors who have actively been involved in consultations or research in relation to BIM.

Two reliability tests were carried out on 34 dependent variables (potential legal aspects) and 28 dependent variables (appropriateness as contract provisions) based on Cronbach's alpha test. Cronbach's alpha is a measurement of internal coefficient, which is to measure the internal consistency among the variables (Vogt 2007). The results show the intercorrelation scores were 0.83 and 0.89, respectively, for the two sets of variables. The scores were above the acceptable threshold value of 0.7. It can be concluded that the variables are acceptable in terms of internal consistency. In addition, the normality tests were also carried out, where both Kolmogorov-Smirnov and Shapiro-Wilk analyses show the significance value below 0.05 for all dependent variables. In other words, the results indicate that the samples were not normally distributed and nonparametric tests should be used for subsequent analyses.

Table 4 shows a combination of analyses on the variables. All the variables were analyzed using the means and SD. The variables were then grouped into the three predetermined categories. Spearman's rho correlation was adopted to measure the relationships between the legal aspects' variables and appropriateness variables. This nonparametric test is to measure the strength of association between the variables based on their correlation coefficient (Sheskin 2003). The results show all of them were above the significant p-value of 0.05. This means there is a linear relationship between the variables in terms of the agreement scores rated by the respondents.

A total of 22 potential legal aspects were agreed upon by the respondents, which should be considered in BIM-enabled projects. Meanwhile, only one potential legal aspect was excluded from being considered as contract provisions, namely, A8, that the BIM's cost or payment should be charged according to the types of development, models, and functions required for the project. The remaining 21 legal aspects could be used as the potential contract provisions in BIM contracts. The following are the sorted and highly agreed (above means of 1.0) legal aspects and potential contract provisions associated with BIM implementation:

- A specific BIM standard form of contract is required to cover all scopes and project requirements (A1:1.55);
- The relationship among client, designers, and contractors should be clearly defined and connected in the project (A17:1.36, AP17:1.30);
- The digital data should be protected with security for its usage and data integrity (A30:1.33, AP30:1:16);
- A new BIM manager role should be engaged in the project (A14:1.25, AP14:1.05);
- The data providers (designers or contractors) should be responsible and be liable for the inserted data in the model (A32:1.22, AP32:1.25);
- Digital data or information should be treated as a part of the contract document (A4:1.13);
- The contract should define the roles and scopes of works for all parties involved in the project (A15:1.11);
- The contract should define the BIM's goals and quality checks for different stages of development (A16:1.11); and
- The owner of the model or the client can use, access, and reproduce the model if permission has been sought from the copyright owner (A28:1.08, AP28:1.05).

On the other hand, the nonparametric Kruskal-Wallis test was conducted to investigate the agreed contract provisions against organizational background. The test would compare two or more independent samples (organization structure of the respondents) of different sample sizes for the analysis of variance (Hollander et al. 2013). The result shows the respondents had the same agreement on most of the legal aspects and contract provisions regardless of their organizational background. Most of the means groups rejected the null hypothesis, with the significant p-value above 0.05. Nevertheless, Table 5 shows the different view on the legal aspects and/or appropriateness variables when comparing with the respondents' organizational background. Remarks have been made to articulate possible reasons of the differences or potential areas of developments in the future.

Additionally, while a majority of the respondents have been directly involved in BIM-enabled projects, it is still important to know if there are any different views on the agreed upon legal aspects and contract provisions based on their actual experience in BIM. This has a direct connection with the level of adoption and use of BIM, which will influence the results. Table 6 shows only two items with different views when comparing their actual involvement in BIM by analyzing the Kruskal-Wallis test. In other words, the respondents had the same and consistent views on most of the agreed upon legal aspects and contract provisions. The differences were related to the design aspects of the BIM model development.

Discussions and Contractual Framework

The potential legal aspects have been converted into two types of variables to determine their practicality and feasible use in the future BIM-based contract administration. The preliminary contractual framework is then developed to explain the analyzed legal aspects and contract provisions in a systematic manner as illustrated in Fig. 1. The legal aspects and contract provisions have been further categorized into certain subthemes of contract

Table 4. Analyzed Variables

Legal aspects' variables	Mean	SD	Appropriateness variables	Mean	SD	Correlation	p-Value[a]	Categories
A1	1.55	0.55	N/A	—	—	—	—	Agree
A2	−0.63	1.15	N/A	—	—	—	—	Disagree
A3	−0.19	1.06	N/A	—	—	—	—	Undecided
A4	1.13	0.83	N/A	—	—	—	—	Agree
A5	−0.69	1.26	AP5	−0.94	1.19	0.83	0.00	Disagree
A6	0.13	1.24	AP6	0.02	1.13	0.63	0.00	Undecided
A7	0.61	1.15	AP7	0.69	1.09	0.65	0.00	Agree
A8	0.50	1.05	AP8	0.41	1.10	0.88	0.00	Agreed/undecided
A9	−0.72	1.27	AP9	−0.86	1.17	0.85	0.00	Disagree
A10	0.66	1.01	AP10	0.77	0.86	0.63	0.00	Agree
A11	0.66	0.89	AP11	0.83	0.91	0.73	0.00	Agree
A12	0.83	0.97	AP12	0.91	0.90	0.71	0.00	Agree
A13	1.11	0.88	AP13	0.94	0.92	0.70	0.01	Agree
A14	1.25	0.76	AP14	1.05	0.86	0.71	0.00	Agree
A15	1.11	0.78	N/A	—	—	—	—	Agree
A16	1.11	0.82	N/A	—	—	—	—	Agree
A17	1.36	0.86	AP17	1.30	0.70	0.36	0.03	Agree
A18	−0.16	1.13	AP18	−0.58	1.27	0.72	0.00	Disagree
A19	0.16	1.40	AP19	0.13	1.29	0.77	0.00	Undecided
A20	0.36	1.35	AP20	0.22	1.33	0.91	0.00	Undecided
A21	0.33	0.98	AP21	0.25	0.99	0.84	0.00	Undecided
A22	0.30	0.98	AP22	0.22	1.01	0.78	0.01	Undecided
A23	1.11	0.82	AP23	0.97	0.84	0.675	0.00	Agree
A24	0.38	1.17	AP24	0.47	1.15	0.71	0.00	Undecided
A25	0.69	0.88	AP25	0.55	0.87	0.89	0.00	Agree
A26	1.11	1.00	AP26	0.97	1.02	0.86	0.00	Agree
A27	1.05	1.09	AP27	0.97	1.05	0.856	0.00	Agree
A28	1.08	0.84	AP28	1.05	0.75	0.60	0.00	Agree
A29	0.08	1.25	AP29	0.36	1.19	0.84	0.00	Undecided
A30	1.33	0.75	AP30	1.16	0.87	0.83	0.00	Agree
A31	1.05	0.95	AP31	0.91	0.99	0.78	0.00	Agree
A32	1.22	0.95	AP32	1.05	0.98	0.77	0.00	Agree
A33	1.08	0.93	AP33	0.86	0.99	0.56	0.00	Agree
A34	0.86	1.17	AP34	0.86	0.99	0.82	0.00	Agree

[a]Spearman's rho correlation—linear relationship between the legal aspects' variables and appropriateness variables.

administration. The framework provides a clear linkage of the grouped legal aspects and contract provisions throughout the contract lifecycle. For instance, the contract form will define the roles and model development, and subsequently the digital data from the model development will be governed by data management and copyright. Meanwhile, the payment and penalty will be confirmed at the postcompletion stage of data management. Generally, the legal aspects and contract provisions under contract structure and

Table 5. Different Views according to the Respondents' Background

Variables	Significance	Remarks
Relationship among client, designers, and contractors should be clearly defined and connected in the project (A17).	0.04	The unclear relationship is mainly referred to as the current working relationship among client, designers, and contractors. The designers seem reluctant to have additional legal obligations throughout the BIM model development that is full of uncertainties. Yet, the respondents agreed to clarify this unclear relationship as a contractual relationship to enforce and govern the interests and risks involved in the project.
Designers who develop the model own the rights of copyright when the model is created (A27 and AP27).	0.01, 0.01	There is yet a commonly accepted guideline to calculate the appropriate proportion of rights for the developed model from the designers' perspective. It creates certain doubts on whom and what should be claimed for the copyright in the model. Therefore, a transparent and well-defined copyright policy should be explained and enforced at the beginning of the contract.
Party that hosts the model should include the use and access, recordkeeping, and warranty and preserve the model for the agreed duration (AP33).	0.03	Data security is a critical issue especially dealing with BIM's digital data. The possible different view on this contract provision is the unclear and additional responsibility and expertise required in handling the digital data. The party that hosts the model could work with another specialized computing company that would provide the required server and data security throughout the project lifecycle.

Table 6. Different Views according to the Respondents' Actual Involvement in BIM

Variables	Significant	Remarks
Established standards and guidelines should be applied or followed throughout BIM model development (A11, AP11).	0.02, 0.03	The level of familiarity on the established standards and guidelines will be subject heavily to the actual and hands-on experience in BIM development. The stakeholders and contracting parties should agree in advance for some established standards and guidelines, such as the required level of detail for the BIM model according to the level of development (LOD), format for exchanging the digital data using IFC, and specification for facility management according to Construction Operations Building Information Exchange (COBie).
Designers who develop the model own the rights of copyright when the model is created (AP27).	0.04	The different view could be due to the unclear contributions made by the designers in the BIM model. The designers require making clear the scopes of the model development at the outset of the project. It will avoid any confusion in terms of claiming the model's copyright.

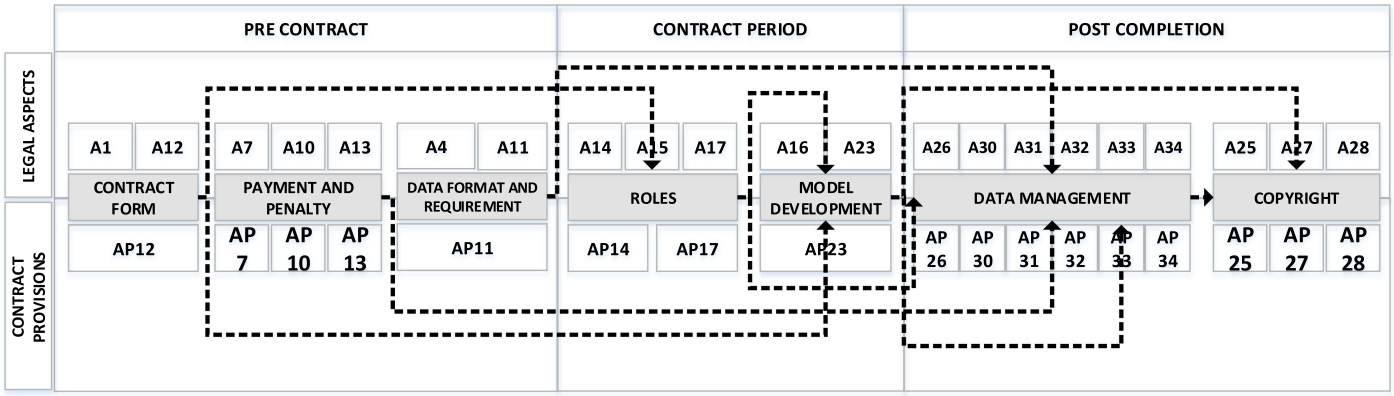

Fig. 1. Contractual framework

policy are the backbone and foundation for the BIM-based contract administration. They are supported by the related contractual relationships and obligations, while the BIM model and security are extended from the governed relationships and obligations of the stakeholders. Yet, there are still many unclear legal requirements for the contract structure and policy, and the contractual relationships and obligations compared with the BIM model and security. These two categories could be further clarified and synchronized through selecting an appropriate procurement system and complying with related laws in the country. The legal requirements for BIM model and security are rather straightforward because this non-human-oriented category merely needs a clear set of rules to deal with the required technical characteristics in the model.

Additionally, most of the agreed upon legal aspects could be used and rephrased as contract provisions in BIM contracts. The determination of the contract provisions is critical to regulate and enforce the new practice (Lu et al. 2015), for which the contract is the right tool and adaptation mechanism (Schepker et al. 2014). The regulated BIM practice will provide twofold implications. First, it will help in promoting a greater adoption and use of BIM in the AECO industries, especially for developing nations. Second, it will help in providing industrywide solutions by standardizing and maturing the BIM-based contract administration throughout the project lifecycle.

Apart from that, three limitations or concerns require further explanations by considering the ongoing developments of BIM and the use of Kruskal-Wallis tests. Building information modeling is evolving and integrating with other advanced technologies for better use and development in industries. The related legal aspects and contract provisions might need modifications to accommodate the technological innovations in the BIM practice. This is a rather different perspective in contract administration because construction contracts are usually revised to accommodate the updated and developed laws. This different perspective is practical for BIM in the AECO industries by considering innovation theories, which is to integrate the technological innovations with the required administrative aspects (Daft 1978).

Next, Kruskal-Wallis tests were conducted against the independent variables of organizational background and actual experience of BIM. Apparently, Mann-Whitney U test should be carried out to investigate the details of the independent variables; however, the limited sample size for each pair of subvariables would create unstable results. Nevertheless, the results from Kruskal-Wallis were able to draw a clear and detailed comparison on the agreed upon legal aspects and contract provisions against the independent variables based on its group means analysis. The implications of the comparison are significant and relevant to uphold a true collaborative platform in BIM-enabled projects without targeting certain groups or subvariables in this situation. Hence, some agreed upon legal aspects (A11, A17, and A27) and contract provisions (AP11, AP, 17, AP27, and AP33) require further research and investigation. The client who is the paymaster should always take an initiative to create a common goal under a well-balanced risk and profit-sharing system with the project stakeholders (Chong et al. 2016).

Although the majority of the respondents are highly educated and have had more than 10 years of working experience; they

may not have the decision-making abilities in the contract administration process. Their responses were mainly based on their practices and desires in the BIM-enabled projects. Nevertheless, this concern should serve as a limitation of the research, with future research investigating from the perspective of decision makers in contract administration. This will enhance the correlation the between the needs of field personnel and the top managerial team when incorporating the necessary contract provisions into BIM contracts.

Conclusion

This research has identified a total of 34 potential legal aspects under three main categories: (1) contract structure and policy, (2) contractual relationships and obligations, and (3) BIM model and security. A total of 22 of them are relevant and should be considered in BIM-enabled projects according to the analysis of the questionnaire survey. Meanwhile, 21 of the legal aspects could be used as contract provisions required in BIM contracts. Subsequently, a preliminary contractual framework has been developed by referring to the analyzed legal aspects and contract provisions. The proposed framework connects all the related subthemes and provides insightful references for future development of BIM-based contract administration.

The key contribution of this research lies in the extension of the existing BIM contract protocols and the related body of knowledge for BIM-based contract administration. It has determined numerous new and potential contract provisions required in BIM contracts under three categories as described in the proposed framework. The findings from this research can be used to help promote and standardize future BIM-based contract administration in the AECO industries.

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