The Relationship Between BIM Implementation and Individual Level Collaboration in Construction Projects

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Abstract. Collaboration is a vital requisite in a multi-participant and multi-disciplinary working environment such as in building design with BIM in the fragmented building construction industry. The design professionals in a project team need to closely collaborate with each other to obtain integrated and high performance design outcomes. However, it is not always possible for construction professionals to achieve a high level of collaboration under the usually chaotic circumstances prevalent in the construction projects. Divergent perceptions at individual, team, and firm levels and the divergent interests of the parties inhibit effective collaboration. The main purpose of this paper is to evaluate the relationship between individual level collaboration and BIM implementation. An extensive literature review was conducted to investigate the characteristics of BIM implementation and to research the factors that affect collaboration at individual level. Metrics were developed to quantify the characteristics of the collaboration between the members of project team and the characteristics of BIM implementation. A questionnaire survey was administered to 256 building design professionals including architects, structural engineers, electrical engineers, mechanical engineers, and the like. The results were analyzed and the relationship between BIM implementation and individual level collaboration between the members of the project team was evaluated. The paper comments on the characteristics of the collaboration, and discusses the factors that affect this collaboration in BIM implementation. It was found that all suggested observed variables well explain the individual level collaboration and BIM implementation. The hypothesized model is significant at \( p \leq 0.001 \) level. The model fit is good. There is a positive relationship between individual level collaboration and BIM implementation. In future studies, it is recommended that the analysis will be carried out on the other levels of collaboration to assess the relationship with BIM implementation and collaboration in construction projects.

1. Introduction

Research on collaboration in fragmented, multi-disciplinary, and chaotic working environments is a challenge because of the difficulties in identifying the level and the distinction in contents of each level. Construction projects’ participants’ relationship and the intension and frequency of the relationship between each other changes according to the plan of activities realized together throughout the project life cycle.

The focus of this study is identifying the relationship between individual level collaboration and BIM implementation in construction projects. The perspective includes the team members as the core individuals in construction projects, which includes the challenge in interdisciplinary collaboration.
This study provides empirical evidence on the relationship between individual level collaboration and BIM implementation.

Jassawalla and Sashittal [1] define collaboration as people’s gathering with diverse interest to achieve a common goal via interactions, information sharing, and coordination of activities. Individual professionals establish collaboration on a mutual objective. However conflicts may occur during project life cycle. Collaborative working environment may be disturbed by inconvenient attitudes and personality differences of individual professionals. These individual level constraints may affect final project outcome. Collaboration via continuous exchange of information and knowledge exists in relationships among individual professionals throughout the project life cycle. Therefore, individual level collaboration heavily relies on the past relational experiences, cognitive perceptions, and trust among collaborators [2].

Project is a temporary endeavor. Individuals from diversified professions come together to enhance a successful end product with preserving their professional objectives within the project organization. Construction projects require interdisciplinary collaboration because of their structure. Each individual professional protect their parent organization’s interest while trying to collaborate with other professionals for a common goal, which is a successful end product with satisfying both the end users and all stakeholders. Therefore, construction projects have a chaotic collaboration environment. Amabile et al. [3] put forth an interdisciplinary collaboration theory. The theory suggests three determinants (Table 1) for successful collaboration, which are; collaborative team characteristics, collaboration environment characteristics, and collaboration processes. Each determinant has its subsections that affect the extent of determinant.

| Table 1. Determinants of Collaborative Success, [4] |
|--------------------------------------------------|
| **Collaborative Team Characteristics**          |
| • Professional-Relevant Skill and Knowledge     |
| • Collaborative Skill                            |
| • Attitudes and Motivation                      |
| **Collaborative Environment Characteristics**   |
| • Communication                                |
| • Initial Clarity                               |
| • Effective Use of Member Capabilities          |
| • Conflict Resolution Process                   |
| **Collaborative Outcomes**                      |
| **Firm Level**                                  |
| • Productivity                                  |
| • Financial Profitability                       |
| **Individual and Team Level**                   |
| • Goal Achievement                              |
| • Effective Functioning                         |
| • Individual Benefit                            |

2. Collaboration and BIM implementation in construction

Researchers like; [3, 4, 5, 6, 7], stated that collaboration enhances competitive advantage, facilitates innovation, and coordinates and supports productivity. The complexity of construction projects requires multi-disciplinary collaboration. Collaborative approach is obligatory for construction project delivery. Interdisciplinary collaborative work environment development on a common platform has become a key indicator for successful project completion in recent years. Construction industry has poor productivity because of its fragmented structure. There are improvement in collaboration strategies with new technologies and methods in construction industry including knowledge...
acquisition, knowledge sharing, and interactive working platforms, etc. However, each project participant has own interest to the project according to profession areas. Participants’ objectives and intention in projects are the result of their responsibility area in the field. The main aim and behaviour of each member differs according to responsibility area. The fragmented structure of the industry triggers dissociation in working environment, which in turn leads the disintegration in the end product. Disintegration within the project life cycle leads failure in the project results. Misalignment in the project activities of participants can be managed through the intention of collaboration in all project processes. The end product of construction industry is a building or a structure. All project activities are carried out on a common groundwork to uncover the end product. The provision of this collaborative groundwork is vital to enable specialists from different fields of expertise to collaborate on a successful project. Therefore, in order to realize collaboration in the construction industry, there is a need for technology and methods that will form the groundwork. The researchers report significant failure in project performance or user/participant satisfaction due to the lack of effective collaboration [7]. Building information modelling is an up-to-date method and the building information model is a useful tool for enabling collaboration in construction projects. Individual professionals, especially design team members, most likely can benefit from opportunities offered by BIM method. However, there is not any empirical evidence in defining the relationship between BIM implementation and individual level collaboration in construction projects. There is a lack in existing literature and practical BIM implementation in providing a clear understanding of what exactly promotes the collaboration in BIM enabled project and why collaboration is needed for the success of BIM implementation in a construction project. BIM is a reputable method for efficient and effective project delivery in construction industry. Jassawalla and Sashittal [1] mention that high levels of integration do not represent high levels of collaboration. However, the characteristics such as; willingness to cooperate and willingness to share knowledge in collaborative environments may lead project success.

BIM enhances collaboration involving integrated implementations of diversified background professionals in construction projects. As Succar [11] states project participants can benefit at highest level through implementation of BIM method. The information model produced through BIM methods allows individual professionals and teams to diagnose the problems of the project and to enhance effective work. BIM definition according to AIA is “a digital representation of physical and functional characteristics of a facility” (AIA 2007:53). BIM facilitates a collaborative platform for each project participant to acquire information and share knowledge and via the model. Robust information acquisition and knowledge sharing opportunities obtain an effective communication, which allows to exchange clear, accurate, up-to-date information among project participants and feeds reliable knowledge for decision making. The other definition for BIM stated by AIA is “BIM is a shared digital representation founded on open standards for interoperability” (2007:53), which indicates the requirement for collaboration for utilizing BIM implementation. Succar’s [11] introductory framework for BIM identifies 4 main stages as; pre-BIM, object-based modeling, model-based collaboration and network-based integration. BIM project requires high level of data, information, and knowledge transmission among participants throughout the project life cycle. Eastman et al. [8] suggest that integrated project delivery in construction is the ultimate goal, which requires high collaboration level among all project participants as individuals, teams, and organizations. BIM is superior to traditional construction delivery methods with its ability to enhance collaboration as a platform servicing to all professionals and others. BIM’s superiority in collaboration and effectiveness in knowledge flow approaches is mentioned by researchers such as; Bryde and others [9, 10, 11] claims BIM improves construction quality and efficiency exponentially. However, business and contract models in use do not promote BIM implementation and collaboration actively. Robust BIM implementation can enhance high level of collaboration in multi-disciplinary working environment [12]. BIM enabled projects have shortcomings mostly in software adaptation and coordination defects [9]. There are scarce resources in exposing the complexities of collaboration in BIM implementation studies. Individual participants’ self-interest, parent organization’s strategic goals, and project objectives must be aligned for effective implementation of BIM. Collaborative
process has a vital importance in successful BIM implementation. Individual professional level, 
team/group level, and organizational level collaboration have its own dynamics as well as common 
points. BIM implementation can be achieved within the optimal conjunction of knowledge, 
technology, and collaborative relationships and applications. This paper considers the collaborative 
issues of BIM implementation in relevance with individual professional level.

The objective of this research is to show the relationship between individual level collaboration and 
BIM implementation in construction projects. Based on an extensive literature review of collaborative 
approaches in other industries and the importance of collaboration in construction projects, this paper 
develops a model for individual level collaboration and BIM enabled projects and tests it. Developing 
such a measurable framework of individual level collaboration will explain whether higher level of 
collaboration at individual level is associated with successful BIM implementation or not.

3. Methodology
The research involved constructing a measurement scale for individual level collaboration and BIM 
implementation metrics by performing an extensive literature review to investigate the factors that 
affect the extent of individual level collaboration and BIM implementation. Individual level, within 
the construction project organizational structures, is determined as the participants of the core project 
team. Questionnaire survey was administered to 256 design professionals including architects, 
structural engineers, electrical engineers, mechanical engineers, interior designers, and the like. A 
structural equation model, representing the flow of possible impact direction was developed. The 
collected data were analysed with Structural equation modelling. The software used in the analysis 
was a computer package called SPSS Amos version 22.0. Factor analysis for both individual level 
collaboration and BIM implementation were analysed. The relationship between BIM implementation 
and individual level collaboration was evaluated. The results were discussed.

4. Results and Discussions
The paper identifies the factors that affect the extent of individual level collaboration and BIM 
implementation. The paper also comments on the relationship between individual level collaboration 
and BIM implementation. It was found that all suggested observed variables well explain the extent of 
individual level collaboration and BIM implementation. The hypothesized model is significant at \( p \leq 0.001 \) level. The Relative chi-square value is acceptable with 2.3 value and model fit is good. There is 
a positive relationship between collaboration at individual level collaboration and BIM 
implementation.

4.1. Individual level collaboration factors and BIM implementation factors
Figures 1, 2, 3 show individual level collaboration factors (5 factors, Figure 1), BIM implementation 
factors (4 factors, Figure 2), the relationship between individual level collaboration and BIM implementation (9 factors, Figure 3) respectively. Notes for model in the right side of Figure 3 represent the general information of the evaluated variables. The factor loadings (Tables 2, 3, 4) of 9 variables have statistical significance at \( \alpha = 0.001 \) level The parameter estimates in the Table 5 represent path coefficients and determine the strength of the relationship between observed variables and latent variables or between latent variables [15]. The path coefficients in the model (Figure 3 and 
Table 4) was statistically significant at \( \alpha = 0.001 \).

The data collected in the questionnaire survey were tested for content validity and convergent 
validity as well as the reliability of the constructs. Finally, the goodness of fit of the models was 
assessed. An extensive literature review was conducted to ensure content validity. Cronbach’s alpha 
coefficient [16], which is used for testing internal consistency, ranges between zero and one. The 
Cronbach alpha coefficients are presented in Table 2 and 3. Convergent validity is assessed on the 
basis of the level of significance of the factor loadings. The internal consistencies of the two 
constructs, that are used in the model, were assessed by calculating their Cronbach’s alpha coefficients 
[16]. Internal consistency ranges between zero and one. According to Churchill [17], coefficients
between 0.6 and 0.7 are acceptable for exploratory studies, whereas [18] and [19] consider 0.7 and higher to be preferable and 0.8 or higher to be good reliability. The analysis was conducted by using SPSS version 22.0 on data collected in the questionnaire survey.

**Table 2.** Regression weights for individual level collaboration

| ILC1  | Estimate | P  |
|-------|----------|----|
| ILC2  | .86      | ***|
| ILC3  | .94      | ***|
| ILC4  | .93      | ***|
| ILC5  | 1.00     |    |
| ILC6  | .92      | ***|

**Figure 1.** Individual level collaboration factors

There are 5 Individual level collaboration factors (Figure 1) (relevant to core team members group), [20].

- ICL1 Technical Skills
- ICL2 Openness to share
- ICL3 Engagement in each other’s work
- ICL4 Openness to communication
- ICL5 Establish personal relationships

**Table 3.** Regression weights for BIM implementation

| BIMp1 | Estimate | P  |
|-------|----------|----|
| BIMp2 | .94      | ***|
| BIMp3 | .66      | ***|
| BIMp4 | .55      | ***|

**Figure 2.** BIM implementation factor

There are 4 BIM Implementation factors (Figure 2) (relevant to core team members, decision support, strategic support groups) [20]

- BIMp2 Availability of BIM technology
- BIMp3 Building technological infrastructure for collaboration
- BIMp4 Cyber security in diversity in data sharing

**4.2. A structural equation model: the relationship individual level collaboration and BIM implementation**

The goodness of fit of a model describes its fit to data acquired. The discrepancy between observed values and the values expected under the model is summarized by measures of goodness of fit. The chi square test is sensitive to the size of the sample and of the correlations in the model. \( \chi^2 / \text{df} \) (Chi square / degrees of freedom) is called relative chi-square or normal chi-square [29]. Conservative use calls for rejecting models with relative chi-square greater than 2 or 3 [13, 21, 22, 23]. As recommended, the overall fit of the structural model was also assessed using a number of other goodness-of-fit tests, which included the Goodness of Fit Index GFI - above 0.76) [24], the Comparative Fit Index (CFI - above 0.73) [25, 26], the Tucker-Levis Fit Index (TLI - above 0.70) [24], and the Root Mean Square Error of Approximation (RMSEA - ≤ 0.1) [27, 28, 29].
Figure 3. The relationship between individual level collaboration and BIM implementation

Table 4. Regression weights for ILC and BIM implementation

|                          | Estimate | P  |
|--------------------------|----------|----|
| BIMp <--- ILC            | .52      | ***|
| ILC1 <--- ILC            | .86      | ***|
| ILC2 <--- ILC            | .94      | ***|
| ILC3 <--- ILC            | .93      | ***|
| ILC4 <--- ILC            | 1.00     |    |
| ILC5 <--- ILC            | .92      | ***|
| BIMp1 <--- BIMp          | 1.00     |    |
| BIMp2 <--- BIMp          | .94      | ***|
| BIMp3 <--- BIMp          | .66      | ***|
| BIMp4 <--- BIMp          | .55      | ***|

Table 5 shows the results of the goodness of fit tests for the SEM model. In the model the $\chi^2$/df ratio of 2.347 was below the recommended maximum of 3.00 [30]. Similarly, RMSEA of 0.048 was below the level of 0.05 and indicates a good fit. Additionally, GFI, CFI, and TLI were all close to 1 and indicated a good fit.

Table 5. Model fit for the relationship between individual level collaboration and BIM implementation

|                     | GFI | AGFI | NFI Delta1 | TLI rho2 | CFI | P  | CMIN/DF | RMSEA | PCLOSE |
|---------------------|-----|------|------------|----------|-----|----|---------|-------|--------|
| Model               | .918| .859 | .873       | .863     | .901| .000| 2.347   | .048  | .000   |

5. Conclusions
The proposed model was tested at $p \leq 0.001$ significance level. The research posits that ‘the extent of individual level collaboration affects the extent of BIM implementation. As seen in Figure 3, the path coefficient of 0.52 that represents this relationship is statistically significant and positive. This result suggests that individual professionals collaboration intentions and individuals’ openness to collaboration, openness to share, engagement in each other’s work, establish personal relationships and technical skills affects BIM implementation. The effectiveness of collaboration may increase with
not only individual efforts but also team, and firm level efforts. The successful application of individual level collaboration may lead guaranteed goal achievement, effective functioning of individuals, and self-improvement of individuals with beneficial collaboration efforts. The future researches should focus on team, and firm level collaboration and its effect on BIM implementation. Thus, the overall picture of the relationship among individual, team, and firm level collaboration in construction firms and BIM implementation can be achieved.

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