## HIGHLIGHTS

- We formulate a hypothesis to test if IPD is correlated with BIM implementation in UK
- Using a relativist ontological approach, we test this hypothesis
- We show that there is a positive correlation between the two
- We demonstrate IPD can improve UK construction by defragmenting parties
- We attest that IPD can facilitate BIM implementation in UK

# FACILITATING BUILDING INFORMATION MODELLING (BIM) USING INTEGRATED PROJECT DELIVERY (IPD): A UK PERSPECTIVE

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## Abstract

The Construction industry is a major player in the UK economy and is in need of continuous improvement. In an attempt to do so, in 2011 the UK government made Building Information Modelling (BIM) level 2 a mandate for all public projects by 2016. Integrated Project Delivery (IPD) is a project delivery approach closely attributed to BIM. However, it does not seem to have received proportionate level of attention and uptake in the UK. The research into reciprocal impacts of BIM and IPD are few and far between and non-existence in the UK construction context. This research investigates if and how IPD can facilitate BIM implementation in the UK. Capitalizing on relativist ontology, the study uses a mixed methodology to gauge the industry experts' perception of the barriers to BIM implementation and uptake and the barriers to what constitutes IPD principles based on what has been found in the literature. The research findings support the hypothesis that IPD does help overcome barriers to collaboration, improve early involvement of the key participants and enhance the level of trust among key stakeholders; thereby helping eliminate the barriers to implementation of BIM. The research has also identified the main barriers to implementing IPD, which if overcome, could improve construction performance in terms of cost, time, efficiency and productivity in UK by defragmenting parties through its multi-party agreement structure, facilitating BIM, enhancing parties' early involvement and collaboration through its inherent BIM contractual principles. The findings suggest that IPD can facilitate better and wider uptake of BIM in the UK construction industry.

**Keywords**: Building Information Modelling, Integrated Project Delivery, Project Delivery Methods, BIM Implementation, IPD Facilitation.

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# 1. Introduction

The construction industry is one of the major sectors of the UK economy as it contributes over £90 billion to the economy and offers 2.93 million jobs provided by more than 280,000 companies (Rees et al. 2013). This sector has experienced a decrease in the UK's gross value added (GVA) from 8.9% in 2007 to 6.7% in 2011 as it was disproportionately affected by the recession in 2008 (Rees et al. 2013). Worryingly enough there is a recurring pattern in the UK construction industry which, although frequently picked up by several independent studies or task force commissions (Egan 1998; Latham 1994; Wolstenholme et al. 2009), it does not seem to have been acted upon. Following upon what started over two decades ago, more recently Farmer's report (2016) asserts: "Deep-seated problems have existed for many years and are well known and rehearsed, yet despite that, there appears to be a collective reluctance or inability to address these issues and set a course for modernization". In this regard, lack of value for money, time/budget overrun, unreasonable running and maintenance costs, unfitness for purpose, lack of skilled labor, and lack of standardization added by need for more off-site prefabrication to improve integration and coordination between design and construction are just to name a few. Construction projects face many issues of which some seem to have been caused by the delivery models. This has resulted in the industry yearning for alternative procurement methods, where a more collaborative culture can replace and improve the fragmented nature of the industry.

In April 2011, the UK Government mandated Building Information Modelling (BIM) Level 2 for all public projects in the UK by April 2016. BIM Level 2, was described by Bew and Richards, in their 4-level (0 to3) BIM maturity model (Figure 1), as "collaborative BIM", where federated information models will be shared within a Common Data Environment (CDE).

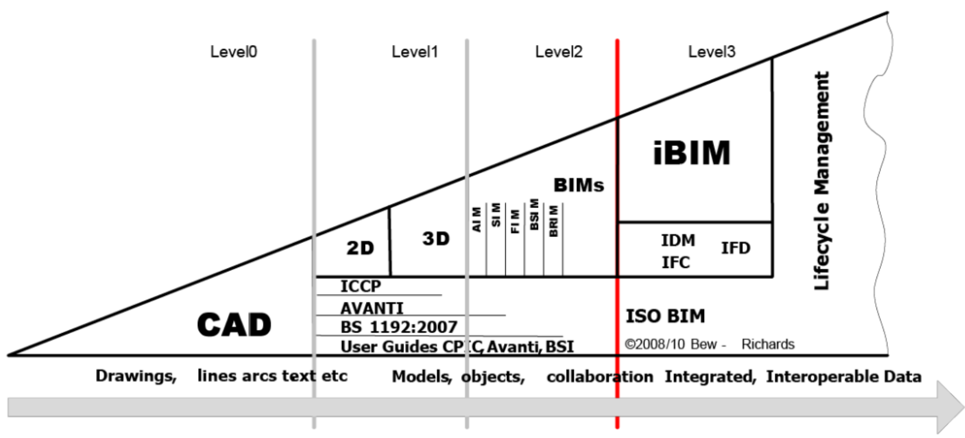


**Figure 1: BIM Maturity Levels**

The fact that this technology has the ability to satisfy the need for improved communication between stakeholders has led to it receiving a lot of support from a number of sources (Azhar 2011; Azhar et al. 2008; Azhar et al. 2012). Integrated Project Delivery (IPD) was introduced in the US (Ghassemi and Becerik-Gerber 2011) to form a construction paradigm that targeted the improvement of the project cost, time and quality over traditional procurement systems. The American Institute of Architects (AIA) emphasize that although BIM can be implemented in most of the procurement systems, it would be in its best usage if it is implemented within IPD (AIA and AIA California Council 2007). Existence of BIM and IPD show the opportunity to shift from the traditional to modern paradigm as a result of their advanced function and strength of cooperation (Yang and Wang 2009).

The UK construction industry has made numerous attempts to improve collaboration amongst key stakeholders and to reward high performance teams, such as encouraging partnering. The advancement of IPD and its coupling with BIM could suggest, in theory, that potential improvements can be introduced in this regard. Despite progresses made in introduction, implementation and acceptance of BIM – which inherently thrives on collaborative working processes, there is very little evidence to suggest that a proportionate adoption of IPD (in relation to BIM or otherwise) has taken place in the UK construction industry. Furthermore, there is no such evidence to support that there is a move in that direction or that a sensible change in the existing profile of prevailing procurement methods in the UK has or is set out to emerge.

With this brief introduction, a number of questions will arise such as: what are the barriers to implement BIM in the UK building construction industry? Will IPD help eliminate barriers to BIM implementation in the UK building construction industry? If IPD is taken up to, how can it facilitate the implementation of BIM? The aim of this study is to investigate the possibilities and limitations for IPD to facilitate BIM implementation in the UK construction industry. In order to achieve this aim, a hypothesis has been developed to find out if IPD facilitates BIM implementation, that is: "IPD facilitates overcoming BIM implementation barriers".

To fulfil the aim of this study and answer its research questions, this paper starts with a critical review of literature to identify the barriers to BIM implementation, nomenclature, concept and principles of IPD and finally to couple BIM and IPD through review of the state-of-the-art. The factors identified will then be used to design the research instrument which will have two different but not mutually exclusive sections to cover both quantitative and qualitative components of this research. This will be discussed in more details under research design and methodology section. Then data collection and analysis will be elaborated on where the hypotheses which were formulated in research design and methodology section will be tested. The result analysis will be followed by discussion of findings and concluded in the last section, concluding comments where some recommendations for future research will be provided.

# 2. Literature review

## 2.1. BIM: Barriers to implementation

Scott et al. (2013) define BIM as a modelling technology and associated set of processes to produce, communicate, and analyze building models. BIM is a tool for collaboration and a tool to integrate our fragmented building industry. BIM is also a process that allows project stakeholders to collaboratively manage the fundamental building design and data in a format that is understandable for all participants from early stages of the project and throughout its life cycle (Azhar 2011; Becerik-Gerber and Kent 2010; Glick and Guggemos 2009; Succar 2009; Thomsen et al. 2009). Thompson et al. (2009, p.50) mention BIM characteristics as: "plug-ins, reports, 4D and 5D models, clash detection, direct fabrication control, facilities management", and eventually BIM as a contract tool. A number of scholars have claimed that the main barriers to BIM implementation are the lack of a BIM contractual document and the issues around the implementation and use of BIM as a collaborative framework ((Azhar 2011; Azhar et al. 2012; Kent and Becerik-Gerber 2010; Ku and Taiebat 2011; Porwal and Hewage 2013; Redmond et al. 2012) Thompson et al., 2009). The issue of BIM implementation or its use includes the question of who is responsible for design, who owns the copyright, who has the intellectual property rights, who should develop and operate BIM and how the cost of implementation would be distributed or shared, etc. Azhar et al. (2012), Bernstein and Pittman (2008) and Ku and Taiebat (2011) agree with these issues of implementation and claim that BIM implementation is faced with barriers of interoperability issues, lack of [corresponding] technology, lack of skillful trained personnel and finally lack of collaboration. Most of the mentioned barriers have solutions through IPD (AIA et al. 2012) which seems to make the two innately inseparable.

## 2.2. IPD nomenclature and concept

Initially coined by an air-conditioning company in 2005, IPD started emerging in practice when AIA introduced the first IPD contract in 2007. It appeared as a new delivery system with the potential to provide better performance through more supply chain integration (Mesa et al. 2016). AIA California Council (2007: p1) defines IPD as, "a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste and maximize efficiency through all phases of design, fabrication and construction." IPD has been defined as an alternative contractual agreement among at least three main project parties i.e. client, designer and contractor, that:

- is highly collaborative among these team members (AIA California Council 2007; Autodesk 2008; Cox et al. 2011; Ghassemi and Becerik-Gerber 2011; Kent and Becerik-Gerber 2010; Scott et al. 2013; Sive and Hays 2009);
- mandates the use of BIM with integrating technology into contract (Autodesk 2008; Raisbeck et al. 2010; Sive and Hays 2009);
- facilitates high-performing teams by aligning the team incentives and goals;
- improves Value for Money (VfM) for the clients ((Becerik-Gerber and Kent 2010; Raisbeck et al. 2010) by targeting waste, inefficiency and adversarial relationship that Architecture, Engineering and Construction (AEC) industry is faced with ((Ghassemi and Becerik-Gerber 2011; Lichtig 2006).

Risks and rewards are shared between project members and success of the parties is tied to the project success in IPD (Thompson et al., 2009; (Cox et al. 2011)). They argue that IPD was brought out to make better projects, faster for less. IPD can also create incentives for exceptional results, reduce operational and maintenance costs of the finished project, improve project delivery timelines, and reduce waste through better planning and shared costs (Kent and Becerik-Gerber 2010). However, with hindsight, it should be noted that IPD is not prescribed as a panacea for all problems. Research suggests although IPD may have advantages over other procurement methods in certain project types/sizes, smaller and less complex projects may yield different results (Mesa et al. 2016).

## 2.3. IPD principles

The MacLeamy Curve (AIA and AIA California Council 2007) illustrates the benefits of the fundamental principles of IPD (Figure 2). Design changes late in the project have a bigger cost implication. The time spent on design in IPD is longer than in traditional contracting, due to complexity of IPD projects as more disciplines are involved and integrated to develop design solutions more comprehensively (AIA and AIA California Council 2007; Sive and Hays 2009).

This approach to formulate design solutions is achievable by integrating information and data management horizontally, vertically and temporally in order to improve collaboration, communication, coordination, and decision support (Succar 2009). Fish (2011) states that IPD projects encompass the notion of 'early'. Scott et al. (2013) also advocate the same principle because of the importance of project parameters that have to be established early. It is in the earliest stages of the project that decisions are most effective, hence it is during these stages that the participants' knowledge and expertise combination is most powerful (AIA and AIA California Council 2007). Early involvement is also suggested to be the cure for the fragmentation problems that the industry is faced with and prevent inefficient work practices and costly changes that occur late in the construction phase (Kent and Becerik-Gerber 2010). Scott et al. (2013) and Lévy (2012) believe that one of the most important principles for a successful IPD process is open, honest and enhanced communication between groups, consequently eliminating the segregated roles of traditional contracting processes, which will result in increased value to the client and reduces the amount of construction waste. Although there are some disagreements regarding the order and importance of these principles, all are components of IPD, regardless, and have to be accounted for in order to implement IPD successfully.

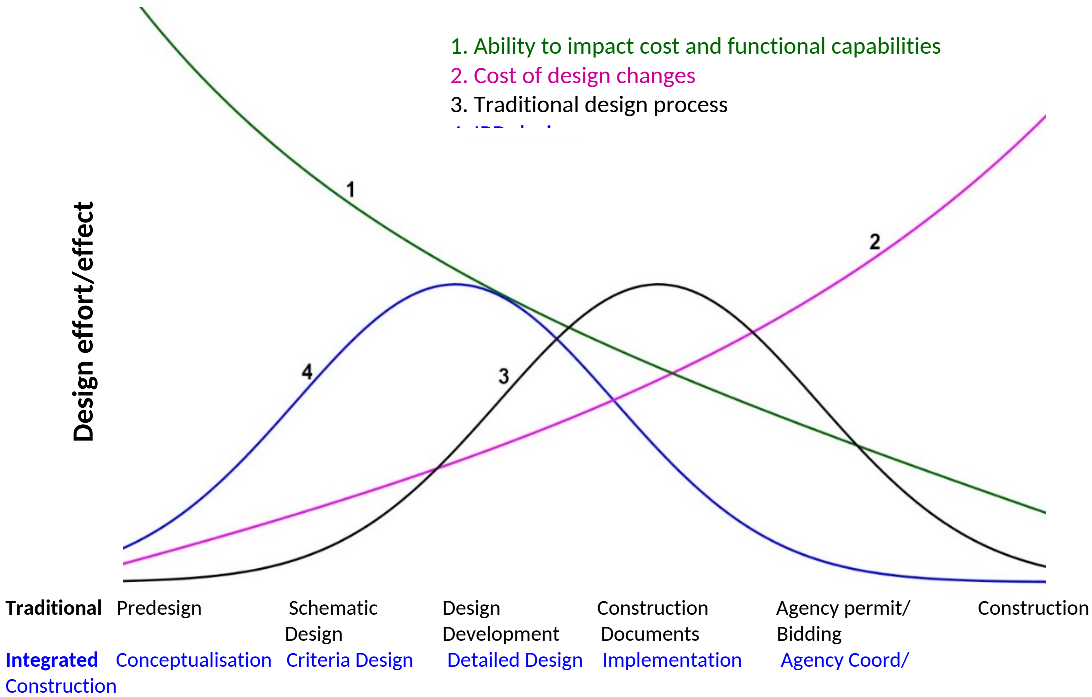


**Figure 2: The MacLeamy Curve (AIA and AIA California Council 2007)**
**(Used with written permission from AIA California Council)**

To summarize, to obtain the maximum benefits of IPD, there are 9 vital principles that have to be implemented in order to increase effectiveness and to facilitate better collaboration. These principles are as follows (AIA and AIA California Council 2007; Becerik-Gerber and Kent 2010; Cox et al. 2011; Fish 2011; Ghassemi and Becerik-Gerber 2011; Kent and Becerik-Gerber 2010)):

- Multi-party agreement
- Mutual respect and trust
- Mutual benefits and rewards
- Collaborative innovation and decision making
- Early involvement of key participants
- Early goal definition
- Intensified planning
- Open communication
- Organization and leadership

These principles are all necessary for a successful collaborative genuine IPD (as opposed to what was called 'IPD-ish' by Sive and Hays (2009)). It is broadly acknowledged that among these principles, 'mutual respect and trust' and 'early involvement of key participants' are the most important principles of IPD (AIA and AIA California Council 2007; Becerik-Gerber and Kent 2010; Fish 2011; Ghassemi and Becerik-Gerber 2011; Kent and Becerik-Gerber 2010; Scott et al. 2013; Sive and Hays 2009).

### 2.4. Coupling BIM with IPD

There is consensus in the literature that BIM is the essential feature of IPD and it is IPD that facilitates the use of BIM effectively for building construction (AIA California Council 2007; Conrad 2013; Kent and Becerik-Gerber 2010; Lévy 2012; Porwal and Hewage 2013; Raisbeck et al. 2010; Scott et al. 2013; Sive and Hays 2009). IPD relieves the barriers to implement BIM as it removes the contractual and responsibilities separations, consequently improving the collaboration environment that BIM implementation necessitates (Azhar et al. 2012; Thomsen et al. 2009). IPD and BIM are contributory, and mutually facilitate and strengthen each other (Thomsen et al. 2009). Jones (2014) investigates IPD and BIM to maximize design and construction considerations regarding sustainability and concludes that BIM is an essential tool and the inevitable future of the construction industry – probably beyond the intended scope of the research. It is however, widely agreed upon that utilization of BIM will improve collaboration, reduce waste and errors, facilitate exploration of alternatives and sharing information, improve construction scheduling and streamline the design and construction of the project (Conrad 2013; Glick and Guggemos 2009; Porwal and Hewage 2013). BIM has been the point of emphasis for IPD as it provides a virtual design before the actual construction begins which enables the project stakeholders to see the building clearly (Lévy 2012; Scott et al. 2013; Sive and Hays 2009). AIA and AIA California Council (2007) agrees and further reinforces the idea by suggesting that BIM enables reuse of information as much as possible. There is no doubt that it is possible to use BIM and IPD separately, but it is the coupling of the two that mutually facilitates the effective utilization of the other.

## 3. Research methodology and design

This study deploys a relativist ontological approach as there is a notable body of knowledge that suggests that the AEC industry is not static but constantly changing due to both external and internal factors. A mixed methodology was therefore deemed the most appropriate for this study. A mixed methodology, which stems from a pragmatic approach, reflects a relativist ontology which accepts that there are multiple forms of reality (Denzin and Lincoln 2017) and that individual theories are not sufficient as worldviews are not static and are influenced by social conditions (Kuhn 1962). This further justifies the use of both quantitative and qualitative data allowing for triangulation. Triangulation is the convergence of the data and consequently adds rigor, breadth complexity and richness (Flick 2002).

Considering the chosen methodology, in order to obtain a rigorous understanding of the relationship between different procurement methods that have been utilized in the UK construction industry, and to find out whether BIM lays the foundation for the UK construction industry to adopt IPD as an ensuing procurement system, initially, a thorough literature review was carried out aiming to analytically review IPD system to elaborate on its principles, prerequisites, characteristics, premises and requirements. In addition, the literature review also assisted to establish the research question and to formulate the research hypothesis in order to generate potential questions for the questionnaire survey. It is worth noting that due to lack of familiarity with IPD in the UK, we had to introduce a new layer of abstraction which started with a targeted review of literature entitled ‘coupling BIM and IPD’, followed up on by developing the main hypothesis into ‘the operationalized sub-hypotheses’, to ensure that IPD principles are translated into the professional vocabulary commonly used in the UK construction industry. These factors, which will be tested through operationalized sub-hypotheses, will then be accumulated to conclude on testing the main hypothesis of this study. A comprehensive questionnaire was produced with an aim to gauge the professionals’ expert opinions on the issues that they have to deal with on a daily basis; issues resulting from the problems and constraints that UK construction industry faces in terms of procurement systems. The questionnaire was also used to investigate barriers that IPD has to overcome to get adopted by the UK AEC industry and how the principles and drivers of IPD are, or can potentially be, responded to within this context.

Based on the research questions which were formulated after the literature review, a hypothesis was shaped to find out the barriers to implement BIM in the UK construction industry:

$\mathbf{H_A}$: IPD facilitates overcoming BIM implementation barriers.

The hypothesis attempts to find out, if the IPD factors are responsive in order to facilitate the barriers to implement BIM. To investigate this hypothesis, a multiple-regression test was carried out between the barriers to BIM implementation, as dependent variables, with factors pertaining to IPD, as independent variables, to find out the embodied correlation among these variables. In order to gain a deeper understanding of the relationship between BIM implementation barriers and IPD factors, the hypothesis was broken down to three sub-hypotheses where each IPD factor was tested against BIM implementation barriers using Spearman's rho correlation coefficient to measure the association between the two. The level of significance for this test was set to 5% ($\alpha$=5%), to achieve a statistically significant Spearman rank-order correlation which means that, if the null hypothesis were true, there is less than 5% chance that the strength of the relationship found could have happened by chance.

# 4. Data collection and analysis

## 4.1. Data collection

The data collection instrument was designed in form of a questionnaire (please see supplementary materials). It was piloted with two academics, two practitioners and two post-graduate taught and research students and then checked for research ethics from both professional practice and academic research viewpoints. A Judgmental sampling (Fellows and Liu 2003) procedure was used to choose professionals with consideration of their expertise, proficiency and experiences. A non-random stratified sampling (Fellows and Liu 2003) process was conducted online via LinkedIn as a professional networking website and the Yahoo group Co-operative Network of Building Researchers. This allowed for a purposive and targeted selection of professionals and stakeholders of building construction projects and particularly the IPD project's core group which consists of clients, consultants (PM, CM, architects, designers, etc.), contractors, suppliers and manufacturers (Glick and Guggemos 2009). Groups of professionals were identified through the website and each group description was checked in order to find the ones that best align with the purpose of this study. In total 58 quality responses to the questionnaire were received over a three-week period. Due to the fact that there are no means of checking how many members have chosen to see, and pursue the survey or how many have opted out before finishing the survey and at what stage, it is very difficult if not impossible at all to comment on the response rate with certainty. The responses received were all complete. They were quality-checked and all deemed valid.

## 4.2. Data analysis method

SPSS was used for data analysis. The data gathered from the respondents was grouped into two set variables; categorical variables and nominal variables. SPSS provided a total score of project satisfaction, BIM implementation barriers, level of trust, level of parties' involvement and barriers to collaboration variables in order to transform the nominal variables to continuous variables. This helps investigate the correlation between variables described in each sub-hypothesis by utilizing Spearman's rho correlation coefficient tests and set of multiple-regression tests. Correlation and multiple regression tests are utilized due to the type of variables, the number of variables and the aim of investigation.

## 4.3. Analysis and results

To begin with, the results of the question aimed at mapping the age of the participants indicated that younger generations had a higher response rate. Among the respondents, 66% were 45 years old or under. This was not far from expected as younger people normally have more inclination towards newer technologies, systems or methods (Figure 3).

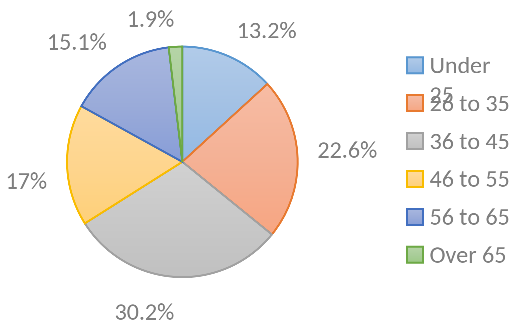


**Figure 3: Participants Age**

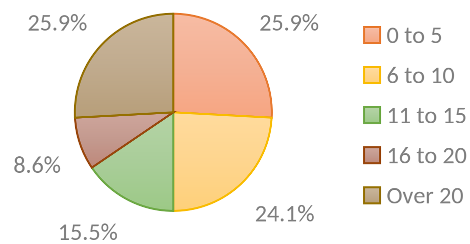


**Figure 4: participants experience**

Also, the respondents were asked regarding their experience in UK construction industry and results indicated that about 74% of the respondents had 6 years of experience or more and half of the respondents had at least 11 years of experience in the UK construction industry (Figure 4).

The majority of the respondents were among the consultants (55.6%), followed by contractors (25%) and clients (15.3%) with manufacturers (2.8%) and suppliers (1.4%) at the bottom. It can point out the fact that suppliers and manufacturers have less involvement in the project initial development which corroborates that they are less interested in the subject.

In response to the question that aimed to identify the main barriers to implement BIM in construction projects, the results indicated that lack of training had the highest ranks of significance with 'significant' to 'very significant' impact on implementation of BIM (61%) followed by lack of software interoperability and lack of collaboration (56% and 50% respectively). Also parties' fragmentation and lack of appropriate planning were identified as the fourth and fifth most significant reasons for those problems (Table 1).

**Table 1: BIM implementation barriers**

| Barriers | Very Insignificant | Insignificant | Neutral | Significant | Very Significant |
|---|---|---|---|---|---|
| Lack of BIM contract | 36.8% | 5.3% | 15.8% | 5.3% | 36.8% |
| Lack of technology | 21.1% | 10.5% | 26.3% | 15.8% | 26.3% |
| Lack of training | 22.2% | 5.6% | 11.1% | 22.2% | 38.9% |
| Parties' fragmentation | 11.1% | 5.6% | 44.4% | 16.7% | 22.2% |
| Lack of software interoperability | 12.5% | 0 | 31.3% | 25% | 31.3% |
| Lack of collaboration | 12.5% | 12.5% | 25% | 25% | 25% |
| Lack of trust between parties | 17.6% | 17.6% | 35.3% | 5.9% | 23.5% |

The lack of BIM contract was classified as insignificant or very insignificant by about 42% of the respondents, followed by lack of trust which was picked up by 35% of participants as insignificant or very insignificant, while about 31% of participants consented that the significance of lack of trust was high or very high. Probably, this can be explained considering the level of trust in those projects which shows that collectively about 69% think the level of trust was of neutral to very low significance (Figure 5).

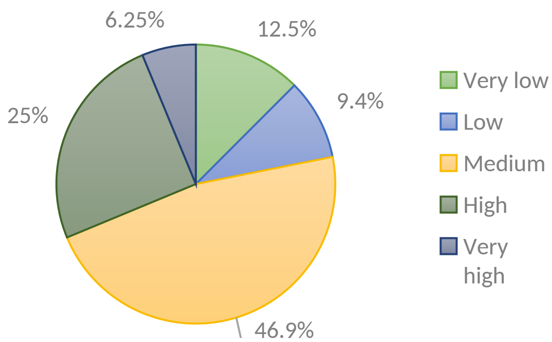


**Figure 5: Level of trust between projects' stakeholders**

Looking at the area of stakeholder involvement (Table 2), while 78% of the participants thought clients had an early involvement in the design stage, 53% believed that installers had a late involvement. Also fabricators, suppliers and contractors have been chosen by 50%, 50% and 44% respectively as the parties with late involvement. It has to be mentioned that 44% of the respondents had a consensus that between these parties, it was the regulatory agencies that had no involvement in the project (Table 2).

**Table 2: Level of stakeholders' Involvement in design stage**

| Stakeholders' Involvement | No Involvement | Late Involvement | Early Involvement |
|---|---|---|---|
| Client | 9.4% | 12.5% | 78.1% |
| Contractor | 18.8% | 43.8% | 37.5% |
| Installers | 31.3% | 53.1% | 15.6% |
| Fabricators | 31.3% | 50% | 18.8% |
| Suppliers | 25% | 50% | 25% |
| Regulatory agencies | 43.8% | 31.3% | 25% |

Investigating the barriers to collaboration, the results show that parties' fragmentation is the most dominant barrier to collaboration with some significant effect, (somewhat significant and significant) at (59%) followed by lack of shared goal and risk allocation method chosen by 52% and 46% respectively (Table 3).

**Table 3: Barriers to collaboration**

| Barriers to Collaboration | Insignificant | Somewhat Insignificant | Neutral | Somewhat Significant | Significant |
|---|---|---|---|---|---|
| Parties' fragmentation | 13.8% | 13.8% | 13.8% | 31% | 27.6% |
| Lack of trust | 6.7% | 20% | 30% | 6.7% | 36.7% |
| Lack of incentives | 13.8% | 3.4% | 48.3% | 13.8% | 20.7% |
| Lack of shared goals | 10.3% | 10.3% | 27.6% | 17.2% | 34.5% |
| Adversarial relationship | 10.3% | 10.3% | 34.5% | 17.2% | 27.6% |
| Risk allocation method | 10.7% | 3.6% | 39.3% | 21.4% | 25% |

## 4.4. Testing the hypothesis

To examine the hypothesis that claims "IPD facilitates overcoming BIM implementation barriers", the null hypothesis was developed as "IPD does NOT facilitate overcoming BIM implementation barriers", representing three sets of independent variables as level of parties' involvement, barriers to collaboration and level of trust. Through SPSS, a total score of each variable was provided in order to transform them from nominal to continuous variables to help utilize multiple regression test to enter all the independent variables (or predictors) into the equation simultaneously to find out how much variance these independent variables were capable of explaining with reference to their dependent variable (i.e. BIM implementation barriers). This offers the opportunity to evaluate each independent variable in terms of its predictive power, over and above that offered by all the other independent variables.

**$H_A$:** IPD facilitates overcoming BIM implementation barriers.

**$H_0$:** IPD does NOT facilitate overcoming BIM implementation barriers.

Standard multiple regression was used to evaluate how the IPD factors' scores predicted BIM implementation barriers. The assumptions of normality, linearity, multicollinearity and homoscedasticity were verified (Tables 4, 5, 6 and Figures 6 and 7).

**Table 4: Descriptive statistics**

| | Mean | SD |
|---|---|---|
| BIM implementation barriers | 19.1905 | 10.17654 |
| Level of parties' involvement | 12.6667 | 3.03864 |
| Barriers to collaboration | 18.4286 | 7.39305 |
| Level of trust | 17.5362 | 6.6453 |

**Table 5: Model summary**

| Model | R | R Square | Adjusted R Square | Std. Error of The Estimate |
|---|---|---|---|---|
| IPD/BIM | .661[a] | .438 | .375 | 8.04503 |

**Table 6: ANOVA**

| | Sum of Squares | DF | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 906.234 | 2 | 453.117 | 170.001 | .006[b] |
| Residual | 1165.004 | 18 | 64.722 | | |
| Total | 2071.238 | 20 | | | |

The variance of IPD factors was significantly related to BIM implementation barriers, $F(2,18) = 170.001$, $p<.005$ (Table 6). The multiple correlation coefficient was 66% ($R=0.661$), indicating that approximately 44% ($R^2=0.438$) of the variance of BIM implementation barriers can be accounted for by the variance of IPD factors (Table 5). This result indicates that the null hypothesis has been rejected, suggesting that the study can confirm the hypothesis claiming that IPD facilitates overcoming barriers to implementation of BIM.

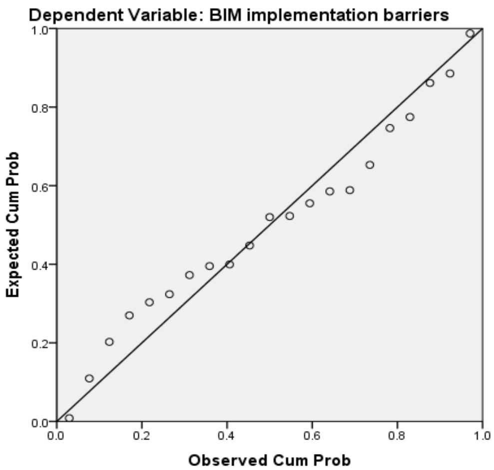


Figure 6: Normal P-P Plot of Regression Standardized Residual 2

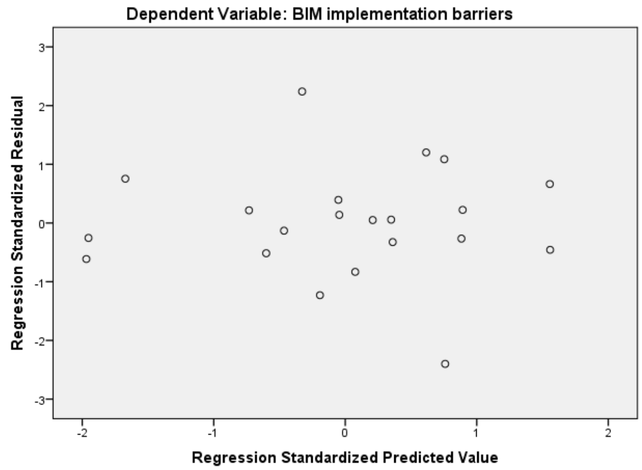


Figure 7: Scatter plot 2

## 4.5. The operationalized sub-hypotheses

In the next step, for better understanding the relationship between IPD and BIM implementation barriers, three sub-hypotheses were introduced, each of which investigates the relationship between each IPD factors (independent variables) and BIM implementation barriers (dependent variable). In order to do this, the study conducted set of Spearman's rho correlation coefficient tests in order to investigate the strength and direction of the monotonic relationship between each independent variable with the dependent variable.

**$H_{A1}$:** there is a relationship between BIM implementation barriers and barriers to collaboration.
**$H_{01}$:** there is NO relationship between BIM implementation barriers and barriers to collaboration.

**$H_{A2}$:** there is a relationship between BIM implementation barriers and level of parties' involvement.
**$H_{02}$:** there is NO relationship between BIM implementation barriers and level of parties' involvement.

**$H_{A3}$:** there is a relationship between BIM implementation barriers and level of trust.
**$H_{03}$:** there is NO relationship between BIM implementation barriers and level of trust.

The relationships between barriers to collaboration, level of parties' involvement and level of trust with BIM implementation barriers were investigated using spearman's rho correlation coefficient. Preliminary analyses were performed to ensure no violation of the assumption of normality, linearity and homoscedasticity exists.

There was a strong positive correlation between the BIM implementation barriers and barriers to collaboration, $r=0.653$, $n=21$, $p<0.05$ with high level of BIM implementation barriers associated with high levels of barriers to collaboration. This result will reject the first null sub-hypothesis and proves the first sub-hypothesis. There was a weak negative correlation between the BIM implementation barriers and level of parties' involvement, $r=-0.296$, $n=21$, $p<0.05$ with high level of BIM implementation barriers associated with low levels of parties' involvement. This result will reject the second null sub-hypothesis and proves the second sub-hypothesis. There was a weak negative correlation between the BIM implementation barriers and level of trust, r=-0.216, n=21, p<0.05 with High level of BIM implementation barriers associated with low levels of trust. This result will reject the third null sub-hypothesis and proves the third sub-hypothesis (Table 7).

**Table 7: Correlation between IPD's factors and BIM implementation barriers**

| | | BIM Implementation Barriers |
|---|---|---|
| Barriers to collaboration | Spearman's rho correlation coefficient | .653 |
| | Sig. (2-tailed): | .001 |
| Level of parties' involvement | Spearman's rho correlation coefficient | -.296* |
| | Sig. (2-tailed): | .026 |
| Level of trust | Spearman's rho correlation coefficient | -.216 |
| | Sig. (2-tailed): | .044 |

* Correlation is significant at the 0.05 level (2-tailed).

## 4.6. Qualitative data analysis

The survey had a mixed methodology structure and aimed to collect and collate data themed around the following areas:

- General information and background
- Difficulties and/or deficiencies that may hinder the project success (with respect to BIM's/IPD's principles)
- Roots of those difficulties and deficiencies
- Potential or envisaged solutions
- Additional expert comments to help acquire more insight into the roots of the difficulties/deficiencies

While the first theme (questions 1-4) was merely aimed to help understand and introduce the research landscape and its participants' demography, the next three themes (questions 5-31) were used for testing the hypotheses. The last theme, which was covered in questions 9 onwards, was used to provide a means for better triangulations of findings. It was also used to investigate more in-depth whether or not the hypotheses of this study hold through when the in-depth qualitative data is queried. It is worth mentioning that although almost all questions were allocated a free-text section so that the respondent could add their expert views if they wished so, not all of the questions received same level of follow-ups. In this section we interrogate parts of the findings pertaining to this last theme.

Question 9 aimed to find out the difficulties that the projects were faced with, in terms of using BIM the results are presented in Table 8, where some of comments were found to be positive (e.g. respondent 5).

Other respondent pointed out collaboration, the very concept BIM is supposed to enhance. This was very interesting as it seems to be a "Catch 22" case; a circle needs to be broken into if BIM is to be facilitated in an orchestrated and systematic manner. Product Lifecycle Management (PLM) and asset management were raised which are also expected to be seen as one of the benefits of BIM not necessarily a hurdle on the way. This may have been raised due to incompatibilities between the ways in which they are currently practiced as opposed to what BIM may introduce as a process change to the existing practices which may require a change management strategy to ensure a soft transition (Table 8).

**Table 8: Difficulties in using BIM**

| | |
|---|---|
| **Respondent 1:** | Collaboration |
| **Respondent 5:** | We found BIM to be very useful and more efficient. It was very useful identifying clashes with other consultants before work started on site |
| **Respondent 31:** | Communication, subcontractors buy in |
| **Respondent 56:** | BIM is often regarded as a document management tool. This industry really needs to think about product life cycle management (PLM), leaving a legacy for asset management |
| **Respondent 58:** | The system is not user-friendly |

Only two participants had additional comments to add to what was already included in the question on barriers of BIM implementation. They believed that because “BIM was not practiced at their organization” and due to “Poor client organization and leadership”, it is difficult to implement BIM. The barriers to build trust between projects’ stakeholders was investigated in question 12, where by contrast, 12 participants chose to share their perception using free text (Table 9).

**Table 9: Barriers to build trust**

| | |
|---|---|
| **Respondent 1:** | Contractual issues, risk allocation. |
| **Respondent 23:** | No barriers. |
| **Respondent 24:** | Very aggressive client, individual ran the project by trying to instill fear of humiliation into each of the consultants and then the contractor. |
| **Respondent 29:** | Arrogance, bad planning, corporate politics. |
| **Respondent 31:** | Changes and variations. |
| **Respondent 33:** | Traditional, professional approach. |
| **Respondent 34:** | Distance of the project form the head office meaning more local unknown supply chain members. |
| **Respondent 41:** | Poor client organization and leadership. |
| **Respondent 42:** | Consultant and the contractor usually have conflicting interest. The other to minimize expenditure and the other maximize profit and protect trade secret. |
| **Respondent 48:** | Parties’ fragmentation. |
| **Respondent 56:** | Survival, forward workload in the context that contractors measure success in volume of turnover. No one ever considers whether it is good turnover. |
| **Respondent 58:** | Lack of awareness of the benefits of open-book policy: poor collaboration between contracting parties. |

While one participant believed there is no barrier to build trust (No 23), many of provided factors were recurring and consistent with what have already been covered in the Likert scale section of this question. Conflicting interest, arrogance, ignorance, poor organization and leadership, bad planning, wrong work culture (aggressiveness, humiliation, instilling fear), parties’ fragmentation were what the respondents raised as some of most important factors. The important point is that some of these barriers are what exactly BIM has set out to address; what can be achieved more specifically through its main contractual framework, namely IPD. There seem to be no ground, reason or justification as to why these very factors are now systemically taking an upper systemic level affecting the implementation of BIM, unless BIM is widely understood and resorted on merely as a new tool, as opposed to a new environment, a new culture and a new paradigm for which to be successful a paradigm shift is inevitable.

When the participants were asked to comment on the reasons for inappropriate decision making in projects, some interesting points were raised (Table 10):

**Table 10: Reasons for inappropriate decision making in projects**

| | |
|---|---|
| **Respondent 8:** | The lack of a decisive project leader. |
| **Respondent 17:** | Not having sufficient information or involvement by construction and supplier teams. |
| **Respondent 27:** | Lack of project ownership. |
| **Respondent 28:** | Different agenda, inexperienced managers. |
| **Respondent 30:** | Arrogance, ignorance, ambivalence, stuck in ones ways, resistance to change. |
| **Respondent 31:** | Pressure from higher management. |
| **Respondent 33:** | Education, lack of. |
| **Respondent 34:** | Too much emphasis on risk transfer instead of retention. |
| **Respondent 41:** | Time allocation to considering options and implications. |
| **Respondent 42:** | Poor planning. |
| **Respondent 48:** | Lack of building information modelling, Lack of earlier involvement of key participants. |
| **Respondent 56:** | Politics, lack of capability. |

Some patterns in this question were similar to what was observed in the previous question, which indeed emphasizes the importance of embarking on BIM and with what the quantitative analysis of this study showed this can be expedited by fully and completely adhering to BIM's facilitators and more specifically IPD which was shown in this study to be one of them. There are obviously some other issues which may not be relevant to IPD, such as: lack of education, lack of awareness and lack of capability (in case we assume that these are chiefly meant to be exclusive to BIM and do not cover IPD). Interestingly, for respondent 48 lack of BIM is the main issue to blame for inappropriate decision making.

Similar question was asked about the reasons for lack of appropriate planning in projects (Table 11):

**Table 11: Reasons for lack of appropriate planning in projects**

| | |
|---|---|
| **Respondent 8:** | Lack of knowledge, and technology. |
| **Respondent 17:** | Pressure on slim teams, for manager to take on multiple projects to "save money", not having the time to plan. |
| **Respondent 27:** | They can be summarized as followings: Inexperienced project manager late involvement of contractors Goals and Objectives are unclear lack of appropriate process. |
| **Respondent 28:** | Unclear agreement on purpose/ functions at outset. |
| **Respondent 30:** | Arrogance, ignorance. |
| **Respondent 31:** | Trust and time to review options available. |
| **Respondent 33:** | Education, lack of. |
| **Respondent 34:** | Skill sets- i.e. BIM specialists and programmers emphasizing too much on construction milestones and not design completion milestones. |
| **Respondent 41:** | Time and human resource allocation. |
| **Respondent 42:** | Unnecessary project fast tracking. |
| **Respondent 48:** | Inadequate incentive, lack of building information modelling, lack of earlier involvement of key participants. |
| **Respondent 56:** | Lack of planning. |

Quite expectedly, many reasons given were not far apart from the ones provided for inappropriate decision making. Some more contract-related factors included (unnecessary) project fast tracking, time and human resource allocation, unclear agreement (on purpose and functions), inadequate incentive, lack of earlier involvement of project stakeholders. Lack of knowledge and [proper/proportionate] technology were also very important reasons highlighted.

With respect to waste in time and resources, the participants who opted in to answer in free-text format link it to other issues which were mutually linked to previous aspects e.g. poor planning, poor decision making or poor communication (Table 12):

**Table 12: Main reasons for waste (time and resources)**

| | |
|---|---|
| **Respondent 8:** | Poor decision making by the client, and designers. |
| **Respondent 17:** | Rushing into concurrent design and build, causes delays and re-work. |
| **Respondent 27:** | Lack of planning and understanding of organisation's resource constrains. |
| **Respondent 28:** | Poor decision-communication. |
| **Respondent 30:** | Arrogance, ignorance, ambivalence, stuck in ones ways, resistance to change. |
| **Respondent 31:** | Collaborative working, pressure from higher management |
| **Respondent 32:** | Pondering over risk allocation by one party driving too hard a bargain for the consideration of others. |
| **Respondent 33:** | Lack of incentives. |
| **Respondent 41:** | Poor planning. |
| **Respondent 42:** | Poor planning. |
| **Respondent 48:** | Lack of adequate technology, inadequate training, poor procurmeent route, lack of building information modelling. |
| **Respondent 56:** | Lack of leadership and empowerment from those who are accountable. |

For the main reasons behind time and resource wastage in construction projects, almost all respondents highlighted one or more issues related to decision making, planning, experience, [inappropriate and ill-defined/ill-executed] concurrent engineering, lack of technology/training/awareness and overthinking by one party which leads to unbalanced risk allocation for the others.

Next question aimed to investigate participants' perception about the main reasons for adversarial relationships in projects, where lack of trust played a major role (Table 13):

**Table 13: Main reasons for adversarial relationships between project stakeholders**

| | |
|---|---|
| **Respondent 8:** | A general lack of trust. |
| **Respondent 17:** | Lack of trust, misaligned goals and incentives between client, designers and construction team. |
| **Respondent 27:** | Lack of appropriate communication and leadership. |
| **Respondent 28:** | Risk management poor and perhaps pricing too "keen" meaning that margins likely to be slim and so need to be enhanced or else protected. |
| **Respondent 30:** | Arrogance, ignorance, ambivalence, stuch in ones ways, resistance to change. |
| **Respondent 31:** | Changes to price. |
| **Respondent 33:** | Vested interests lack of equitable sharing of rewards. |
| **Respondent 41:** | Poor planning, inappropriate appointments, tight budgets, poor leadership and poor communication. |
| **Respondent 42:** | Poor communication and the conflicting nature of contracting. |
| **Respondent 48:** | Lack of trust. |
| **Respondent 56:** | Lack of common goals, misaligned incentives, peronal objectives of influential individuals. |

Lack of trust, poor communication and poor management were the main reasons either pointed out directly or underpinning other reasons directly or indirectly.

The last question with a relatively high qualitative response rate was the one seeking to investigate reasons for lack of communication. The results are shown in Table 14, below.

**Table 14: Main reasons for lack of communication**

| | |
|---|---|
| **Respondent 8:** | Parties trying to protect their own interests. |
| **Respondent 17:** | Pressure to get building, not allowing time for considered responses and complex, communication structure, doesnt allow the key trades/supliers to communicate efficienty. Also client/design team holidays, at key construction points delay problem resolution. |
| **Respondent 27:** | Lack of stakeholder management and understanding their needs and requirements. |
| **Respondent 28:** | Hidden agendas, everyone "too busy". |
| **Respondent 30:** | Arrogance, ignorance, ambivalence, stuck in ones ways, resistance to change, laziness. |
| **Respondent 31:** | Oversight. |
| **Respondent 33:** | Education, lack of. |
| **Respondent 34:** | Some of the "old school" not being acceptable to change. Gen X is "hands on" and real where Gen Y relies on IT, probably too much and considers communication to be via IT only. |
| **Respondent 41:** | Usually time, but often personalities involved. |
| **Respondent 42:** | Lack of trust. |
| **Respondent 48:** | Lack of building information modelling, lack of earlier involvement of key participants, lack of trust. |
| **Respondent 56:** | Not enough time spend in the planning phase, there's always pressure to 'get on with it'. Too many chiefs, demotivated indians. Personal agendas drive isolated decision making. |

Respondents who chose to comment on this question believed that self-protection, hidden agendas, oversights, lack of education (training), lack of trust, work culture and its related issues (e.g. arrogance, ignorance, ambivalence, being stuck with 'old school' and reluctant to change, generation gap, etc.) were the most important reasons for lack of communication. It was very interesting to see how different stakeholders see and frame the same issue from different angles and with different lenses. One example of such cases (which probably will not be flagged in an automated or commissioned text/content analysis) was "being stuck with old school [approach]", "reluctance to change", and "generations X/Y gap".

## 5. Discussion of findings

Do IPD principles address the BIM barriers to facilitate its implementation in the UK building construction industry and if so, to what extent?

Analyses of the results support the hypothesis that IPD does address the barriers to implement BIM in the UK. This is achieved through a multiple regression test, which indicates that there is a significant relationship between IPDs' main principles and BIM implementation barriers (see section 4.4 where it was shown that the variance of IPD principles and BIM implementation barriers were meaningfully correlated, $F(2, 18) = 170.001$, $p<.005$ (Table 6)). Further analyses of the correlation between aforementioned variables demonstrate that IPD has the potential to address some of the key BIM implementation barriers. Literature review revealed that the main barrier to BIM implementation is the lack of a BIM contractual agreement and the issues of implementation and use of BIM as a collaborative framework. Using IPD as a procurement vehicle could facilitate a legal framework and provide the opportunity of eliminating the barriers to collaboration in conjunction with improving the early involvement of the key participants as well as the level of trust between them. Other issues such as the question of who is responsible for design, who owns the copyright, who has the intellectual property rights, who should develop and operate BIM and how the cost of implementation would be distributed or shared, etc. could all be addressed within the contractual agreement. Moreover, the results of the qualitative section of this research served its purpose in providing an in-depth and critical insight to what the participants believed the problems facing their construction projects were. This showed a clear correlation to what the quantitative part of this research found as indicated in the analysis section. Although some issues were pointed out which may have not been included in the quantitative sections, these were either irrelevant to what may concern BIM and/or IPD or were merely a variation of the recurring concepts in the quantitative sections.

Correlation between variables of the BIM implementation barriers and barriers to collaboration is large and positive ($r=0.653$, $n=21$, $p<0.05$; see section 4.5, table 7). This can be justified by another part of the data as well as literature that lack of collaboration is one of the main barriers to the implementation of BIM. The reasons for the lack of collaboration have been identified as parties' fragmentation, lack of shared goals and risk allocation method. The results also state that the elimination of the barriers to collaboration would be facilitated through "multi-party agreement", "risk and reward sharing", "early goals and objectives definition", "collaborative innovation and decision making" and "open communication", i.e. the IPD principles. The issues raised in qualitative section consented the findings in this area, with lack of communication, lack of common goal and issues related to work culture being amongst the most repeated ones. Therefore, once its principles are applied, IPD is able to provide the collaboration environment that eases the implementation of BIM considerably.

Although the results show that there is a low negative relationship but with significant p values between BIM implementation barriers and level of involvement of key participants ($r=-0.296$, $n=21$, $p<0.05$; see section 4.5, table 7) and the level of trust ($r=-0.216$, $n=21$, $p<0.05$; see section 4.5, table 7), it may be argued that this is referring to direct relationships. There are indirect relationships through other barriers such as parties' fragmentation, inappropriate risk allocation and their associated method and lack of appropriate planning and shared goals, which clearly are affected by level of trust. Again this was confirmed through the comments provided in the qualitative sections, which means although its direct statistical recurrence may be a little bit lower than expected, the severity and impact of it on a case to case basis are by far too significant to be overlooked. These problems would be eliminated through early involvement and trust which are the main principles of IPD. For this reason, IPD has the potential to eliminate the barriers of BIM implementation by bringing the key stakeholders early to the project and building trust between them.

## 6. Concluding comments and future research

The UK construction Industry is faced with projects that finish over budget, over time, with unexpectedly low quality that leaves the stakeholders unsatisfied. These shortcomings mainly originate in the inherent fragmentation of the industry. The fragmented nature of the industry has resulted in correlated deficiencies such as inappropriate decision making, late or no involvement of the key stakeholders in the design stage, and lack of appropriate planning, collaboration, communication and trust between stakeholders.

Moreover, the aforementioned characteristic and its resulting deficiencies have generated barriers to implementation of BIM and collaboration in the projects. This study demonstrated that BIM is faced with barriers such as late or no involvement of the key participants, lack of an integrated BIM contractual document, collaboration and trust. The current study has identified that software interoperability, lack of training, and resistance to change from traditional to advanced communication systems by the professionals, play a significant role in preventing the projects to implement BIM.

IPD's most important factors have been identified as early involvement of the key participants, collaboration and trust. Lack of these principles have been identified in the current study as the main barriers to implement IPD which could help improve the UK construction industry by defragmenting parties through its "multi-party agreement" and facilitating BIM, parties' early involvement and collaboration through its inherent BIM contractual requirements and other key principles such as "mutual respect and trust", "collaborative innovation and decision making" and "early involvement of the key participants". Hence, the industry should address its inherent fragmentation as well as eliminating the barriers to implementation of BIM through addressing the issues such as lack of knowledge, software interoperability, training and advancement.

Building upon the study's findings that IPD can facilitate better and wider uptake of BIM; this research recommends further investigation into the IPD system to find out if it would work in the UK construction industry framework. One of the limitations of this research was the restricted timeframe within which data collection had to be carried out. If this restriction were not in place, it could have been expected that a higher number of respondents would have participated in this research. To add yet another complementary angle to this research, another alternative data collection instrument in form of a face-to-face interview, could have been added to this research to enhance the depth of this research and further substantiate the findings of the quantitative and qualitative sections. Also more targeted investigation based on each stakeholder group could have been carried out; subject to sufficient number of participants in each group. This could have appended more subject-specific results to help develop a deeper understanding of different parties' perception of the correlations between IPD and BIM.

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