# An investigation into how BIM exploitation leads to BIM benefit realisation in construction organisations

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**Abstract.** Building Information Modelling (BIM) has recently attracted substantial attention in the construction industry concurrent with the rise of digital urbanisation and its increased use of digital technology. Organisations in the construction industry have now started paying more attention not only to adopt BIM but also to 'exploit' BIM. Adoption of BIM can make an industry set itself as an example to others. However, exploitation refers to something beyond adoption which seeks more validity and reliability on its outcomes- the real benefits. BIM has the potential to offer a range of benefits. The benefits of BIM are connecting project teams, workflows and data across the entire project lifecycle from the design stage to the construction and operations stages. BIM allows its users to realise better ways of working and receive better outcomes while increasing productivity, efficiency, and sustainability. Although BIM benefits have been on the discussion for a while, it has never been rightly attributed to BIM exploitation. Therefore, this paper aims to see how 'BIM exploitation' offers the promised benefits of BIM at an organisation level. The research employs quantitative means to collect and analyse data from construction professionals in the UK. The questionnaire surveys confirm the trends and relationships between variables in the inquiry and helps creating a robust conclusion on how BIM exploitation leads to BIM benefits.

## 1. Introduction

Although BIM (Building Information Modelling) has been in the discussion both in the construction industry and the academia for more than a decade, the popularity it receives yet remains at a higher level. The main reason for its increased popularity and the progressively increased awareness is claimed to be its perceived benefits (Liu et al. 2021). However, how exactly these benefits can be achieved and under what conditions is yet to be resolved.

Further to how these benefits are realised, there is also an ongoing discussion which gives rise to a dilemma around what is the closest strategy (i.e. BIM implementation or exploitation) that helps realising these benefits. The construction management literature emphasises that BIM exploitation is much closer to its benefits realisation than mere adoption or implementation of it. Given the dilemma of whether BIM exploitation leads to BIM benefits or not, following research questions were formulated.

I. What constitutes BIM exploitation in construction organisations

II. What are the benefits of using BIM in construction organisations?

III. Does BIM exploitation lead to BIM benefits realisation?

## 2. Literature Review

*2.1. Conceptual clarity in the 'Exploitation' of innovative technology*

The exploitation of innovative technologies in construction activities is showing a progressive trend in the recent years (Liu et al. 2021) especially because of its intrinsic beneficial use (Mesároš and Mandiák 2021). Although many researchers have already looked into the benefits offered by BIM to construction, it has been necessary to analyse the benefits in the point of view of 'exploitation' instead of other usage means i.e. 'implementation' and 'adoption'. The innovation management literature clearly distinguishes 'exploitation' from all other taxonomies generally used in relation to the 'use' of a technology. One of the widely accepted notions is that an innovation uptake is a 'progressive sequential process' (Lavikka et al 2021) where it involves progressive and developmental stages that takes place one after the other. This notion explains, for an innovation to take its lift through to the success, it needs to be initiated first, adopted in the wider community, the benefits must be ripened, and a reflective practice is exercised to identify the costs and benefits for continuous improvement. According to this notion, no innovation reaches to its intended destination without completing these sequential stages. Some authors advocate three stage models incorporate idea generation, adoption and implementation (Shepard 1967) while some authors interpret innovation in multi stages: i.e. 12 stage model (Hage et al., 1974). Adding a different view to innovation diffusion, Rogers, (2003) introduces the key actors in the adoption and diffusion chain include innovators, early adopters, the early majority and the late majority and the laggards, besides the innovation champions. However, Rothwell and Gardiner (1985) assert that innovation can bring an immediate value to an organisation or can bring incremental benefit over a time period depending on the extent to which the innovation has reached a certain level (i.e. adoption, exploitation). This ideology implies that the stages implementation and exploitation cannot be characterised as incremental stages as they can also act as two independent stages of innovation. Implementation is carrying out, execution, or practice of a plan, a method, or any design, idea, model, specification, standard or policy for doing something (Khosrowshahi and Arayici, 2012). As such, implementation is an action which goes in parallel with 'exploration' which enable something to actually happen. In essence, innovation can be viewed as a process consisting of interlinked sequential and incremental stages (i.e. ide generation to, adoption, implementation and exploitation) or simply independent one-off stages that are not bound by definitional margins and are subject to change (Egbu 2004).

Zahra and George (2002) describes exploitation is a combination of 'use' and 'implementation' where organisational core competencies and harvesting resources acts as a major role. The latter authors also argue that transformation and exploitation capabilities are likely to influence organisational performance and yields sustainable competitive advantage. They define:

*"exploitation as an organisational capability is based on the routines that allow firms to refine, extend, and leverage existing competencies or to create new ones by incorporating acquired and transformed knowledge into its operations"* (Zahra and George, 2002:190).

In addition to the mainstream literature on exploitation, there is a vast amount of body of knowledge which considered 'exploration' and 'exploitation' as two concepts that go hand in hand. One such study conducted by March (1991) purports "exploitation includes such things as refinement, choice, production, efficiency, effectiveness selection, implementation and execution" (p71). Thus, it implies that 'implementation' is a component of exploitation. The argument made in March 's (1991) study is, both exploration and exploitation and critical for organisational success as conducting exploration itself to the exclusion of exploitation suffer from the cost of experimenting without gaining in the intended benefits of it. It is having excess amount of new ideas but very limited amount of capabilities, competencies and competitive advantages. Similarly, organisations that continue to make benefits on a core competency are very much likely to transform into an inadaptable outdated status (Khosrowshahi and Arayici, 2012). Therefore many authors in this two stems are in favour of finding the right balance between exploration and exploitation (Bosch-Sijtsema,et al. 2019; Karampour, et al. 2021).

On the contrary, there is also an argument about the difficulty in finding the right balance between exploration and exploitation. These difficulties include less certainty, comparatively remote in time and cost, reduce of speed due to resources spend on exploration, reduced attractiveness in market due to improvements in existing procedures itself instead of spreading into new alternatives. On the other hand, Hollen et al (2013) stresses the firm's strong capability in identifying new knowledge is also it's weaker capability in exploiting it, and this makes them fail to translate new knowledge into new products and processes. This refers to the difficulty in maintaining both exploration and exploitation simultaneously.

*2.2. Establishing the construct variables for exploitation*

The modern innovation management literature suggests the terms "incremental" and "radical" (the latter also called "breakthrough") and are frequently used to describe the degree of innovativeness of a product, service, process or business model (Hollen et al 2013). Generally, incremental innovation is defined as the refinement, improvement, and exploitation of existing technology, in business models (Liu et al. 2021). This type of innovations reinforces the applicability of existing knowledge for the improvement of a process and subsequently strengthen the capabilities of incumbent firms and their dominant business strategy. The management of incremental innovation is characterized by reliability, predictability, and low risk. Hence, it can be deduced that incremental innovation as defined in modern management theories has similar characteristics of 'exploitation'.

Building upon the aforementioned literature, this paper suggests; for an organisation to foster through innovative technologies, that organisation must have the ability to exploit the technologies. In the context of 'BIM exploitation', it implies a combination of pre-planning and post-planning processes that helps operating them properly. In other words, both inputs/ enablers and outputs/results. In this paper, the 'position' of 'exploitation' is viewed as an incremental stage of 'benefit realisation' that includes the critical factors of implementation as well. This is influenced by the interpretation provided by Zahra and George (2002). This exploitation include strategic leadership, analysing requirements, gathering all resources and infrastructure, goals intended to achieve out of them, policy standards, installation, configuration, customisation, running, testing, systems integrations, user training, delivery and making necessary changes. The word "deployment" is also used to mean the similar idea in literature. Moreover, there is a wide body of literature supporting the constituents of exploitation identified by Zahra and George in the context of technology/ digitalisation/ ICT (Egbu, 2004) and few particularly in BIM (Khosrowshahi and Arayici, 2012) in construction literature. Thus this research adopts exploitation as a dimension that may influence organisational competitive advantage as such by exploiting the potentials of these strategic tools by refining, extending and leveraging existing capacities, practices or routines and then creating new uses, practices, routines, services or products (Zahra and George, 2002), effectiveness and efficiency (March, 1991) and implementation as senior management leadership, required resources and infrastructure (human and non-human), intended goals, standards and policy initiatives. Thus, the Table-1 below lists the constituents used to explain the collective term 'exploitation'. These constituents were worded and presented as such to reflect and match the context of the exploitation of BIM. The code- 'EXP' denotes the constituent of exploitation. Reflecting upon the three research questions, the first question of 'What constitutes BIM exploitation in construction organisations?' is partially achieved through secondary data. To what extent these variables are exploited is investigated later in this study.

**Table 1.** Constituents of exploitation and implementation (on a general level) used in this research.

| | Constituents for exploitation | Dimension |
|---|---|---|
| EXPBIM1 | Senior management leadership | Inputs/ enablers |
| EXPBIM2 | Required Resources/ infrastructure | |

| | | |
|---|---|---|
| EXPBIM3 | People and their skills | |
| EXPBIM4 | Intended goals | |
| EXPBIM5 | Standards and policy initiatives | |
| EXPBIM6 | Creating new uses | Outputs/ results |
| EXPBIM7 | Effectiveness | |
| EXPBIM8 | Extend and leverage existing competencies | |
| EXPBIM9 | Efficiency | |
| EXPBIM10 | New routines and processes | |

After extensive review of literature, mostly cited benefits of BIM were selected and labelled as 'selected BIM benefits' as listed in Table-2. These variables were fed to a questionnaire survey for further investigation.

**Table 2.** Variables for BIM benefits and challenges

| | Building Information Modelling (BIM) Benefits |
|---|---|
| BENBIM1 | Reduction in the whole life cost of built assets |
| BENBIM2 | Ease of information abstraction through simulations and collaborated visualisation techniques |
| BENBIM3 | Reduction in the overall time, from inception to completion of a construction (with less need for rework and early risk/ clash detection) |
| BENBIM4 | Enable faster and better decisions through greater collaboration |

## 3. Research methodology

### *3.1. An overview of the methodology*

This paper employs a quantitative study that tests theories by examining the relationship between variables identified by the literature. The variables fed into the questionnaire was established from a review of existing literature (please see section- 2 above). These variables are measured, typically on instruments, so that numbered data can be analysed using statistical procedures. This approach involves assumptions about testing theories deductively, building in protections against bias, controlling for alternative explanations, and being able to generalize and replicate the findings (Creswell, 2014).

### *3.2. Sample population*

This research assumes that a case represents a group, and that quantity identifies some specific characteristic of that group and the results inform how generalizable the findings are. First, the sample population was selected to provide a good balance between all sizes (small, medium and large) of organisations to represent the construction sector. The researcher has chosen annual turnover as the measure to determine the size of the firm. Within the unit of 'organisation', subunits were segmented based on organisation hierarchy (strategic, tactical, and operational) of respondents. Random sampling was not a feasible option given the newness of the areas and the existence of specialists in the areas of inquiry. Therefore, non-random, or non-probability purposive sampling, stratified before sampling is applied here. Most importantly, a great effort has been devoted to identifying the most suitable individuals for the study given the fact that they have some sort of involvement/ experience in the implementation or exploitation of BIM.

### *3.3. Research methods*

The questionnaire survey was distributed to a pre-established database of 400 professionals working in the UK construction industry as a ‘web-based online survey’ through JISC (Formerly known as Bristol Online Survey-BOS) and it was able to secure a response rate of 28.75% remaking 115 responses. The survey did not use public URL options. Instead, a specific respondent list was created using the aforementioned sampling technique. By doing this, the researcher was placed in control of who can complete the survey. The questionnaire was highly structured where only close-ended questions were employed to facilitate the respondents.

Canonical correlation analysis is employed to identify and measure the associations among two sets of variables (BIM benefits and BIM exploitations). When there are multiple intercorrelated outcome variables canonical correlation analysis is the most suitable in opposed to spearman’s correlation analysis (Pallant, 2011). Canonical correlation analysis determines a set of canonical variates, orthogonal linear combinations of the variables within each set that best explain the variability both within and between sets. The quantifiable attributes signify how pressing an explanation was within the group surveyed. The correlation number can give a sense of strength as well as the direction of the correlation.

## 4. Findings and Discussion

### *4.1. Descriptive Statistics for BIM exploitation*

To commence the analysis, first and foremost, the demographics of the sample population were presented at aggregate and disaggregate levels for the segmented population (as mentioned in section 3.1). Majority of respondents in construction represented the ‘Construction of residential and non-residential buildings and Civil engineering’ (20%) category and ‘large’ (80%). This gives a hint that from the database of respondents, large organisations have a more tendency to use BIM as business as usual. Whether they are equally successful exploiting is later investigated in this paper. In terms of the job role, 59% represented Senior Management (i.e. Executives, strategic managers, senior managers) roles while 29.6% and 11.3% represented Middle-level and lower-level respectively.

### *4.2. Level of exploitation for BIM*

After conducting the Preliminary analysis on assessing normality and reliability of the data set, the main inferential analysis was begun. Before reach to the questions around BIM benefits and BIM exploitation levels, there was couple of preliminary questions around the extent of BIM use of the respondents. 33.9% responded that they use BIM ‘to somewhat extent’ while 35.7% responded as ‘to a greater extent’. The rest used BIM ‘to a very little extent’. The next was to identify the level of exploitation in the respondents. The four-point Likert scale was first given with values ranging from 1-4, where 1- Not at all apply, 2- To a very little extent, 3- To somewhat extent and, 4- To a greater extent. When the sum of each variable is computed, the higher the sum (or the mean value), the higher the extent to which it is being exploited. The Table-3 below summarises the level of exploitation in BIM.

With reference to Table-3, it is apparent that certain variables has received higher exploitation levels. For example, , EXP7 (The individuals who work with BIM manage to perform their daily tasks more effectively) has received the highest mean score of 3.65 out of the responds for BIM exploitation. This means that, majority of the respondents are in the agreement that they have greatly being able to perform their daily tasks more effectively. This is the only variable that has received the highest median score of 4.00 out of the mean scores for BIM exploitation. Meaning, 'average' respondent believe, (or the 'likeliest' response) that the support they receive from senior management on organisational BIM process is greater than the rest of the measures of exploitation. Second highest mean score for construction reports from EXP1 (The senior management of our company gives the required strategic leadership and support on the entire BIM process) and EXP9 (After adopting and diffusing BIM within the organisation, the company is gradually beginning to operate more efficiently than before) recording a similar mean score of 3.59. Inspection of construction sector medians for BIM exploitation suggests (EXP7, EXP1 and EXP9: Md= 4.00) that majority of respondents are in the agreement that EXP7, EXP1 and EXP9 are the areas that they think their organisations have exploited BIM.

**Table 3.** Descriptive statistics for BIM Exploitation.

| | Construct Variables for EXPLOITATION | Mean |
|---|---|---|
| EXP1 | The senior management of our company gives the required strategic leadership and support | 3.59 |
| EXP2 | We are deploying required resources/ infrastructure to enable the technology use and they are properly stored thin such a way that allow access to all members involved | 3.27 |
| EXP3 | Our technology specific team is appropriately selected with right skills and they are receiving a proper training | 3.32 |
| EXP4 | We have set realistic technology goals (i.e. short term/ medium term/ long term) | 3.27 |
| EXP5 | We are using appropriate standards and policy initiatives that help selection, execution and refinement technology workflows | 3.27 |
| EXP6 | The individuals who work with technology typically create new uses for them | 3.31 |
| EXP7 | The individuals who work with technology manage to perform their daily tasks more effectively | 3.65 |
| EXP8 | The individuals who work with technology extend and leverage their existing individual competencies on the technology by incorporating the new system into their regular job role | 3.32 |
| EXP9 | After adopting and diffusing technology within the organisation, the company is gradually beginning to operate more efficiently than before | 3.59 |
| EXP10 | After adopting and diffusing BIM within the organisation, the company embraces new routines and processes in order to use the system in a better way | 3.21 |
| | Sum of Means statistics | 33.8 |

*4.3. Establishing a correlation between BIM exploitation and BIM benefits*

After checking the dataset for its reliability and normality, a Canonical correlation analysis was employed to identify and measure the associations among two sets of variables. A canonical correlation analysis was conducted using the eight benefits-challenges variables as predictors of the 10 exploitation variables to evaluate the multivariate shared relationship between the two variable sets (i.e BIM benefits and BIM exploitation). The analysis yielded eight functions with squared canonical correlations (Table-4) of .736, .594, .422, .248, .229, .182 and .035 for each successive function. Collectively, the full model across BIM benefit functions was statistically significant using the Wilks's $\lambda = .439$ criterion $F(36, 245.79) = 0.870$, $p < .001$. Because Wilks's $\lambda$ represents the variance unexplained by the model, $1 - \lambda$ yields the full model effect size in an r2 metric. Thus, for the set of eight canonical functions, the r2 type effect size was .551, which indicates that the full model explained a substantial portion, about 55%, of the variance shared between the variable sets.

Table- 4 shows that, out of the 8 overall correlations, only first one is statistically significant at the .05 level. It is important to distinguish the difference between this summary and the pair-wise correlations (Table-5) as the latter gives an understanding of every individual correlation and the former gives an overall picture.

**Table 4. Canonical correlation summary between BENBIM and EXPBIM variables.**

| Canonical Correlations | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Correlation | Eigenvalue | Wilks Statistic | F | Num D.F | Denom D.F. | Sig. |
| 1 | .736 | 1.181 | .160 | 1.816 | 80.000 | 433.511 | .000 |
| 2 | .594 | .544 | .349 | 1.270 | 63.000 | 389.088 | .093 |
| 3 | .487 | .311 | .539 | .959 | 48.000 | 343.571 | .554 |
| 4 | .422 | .217 | .706 | .732 | 35.000 | 296.893 | .868 |
| 5 | .248 | .065 | .859 | .461 | 24.000 | 248.899 | .987 |
| 6 | .229 | .055 | .915 | .432 | 15.000 | 199.162 | .968 |
| 7 | .182 | .034 | .966 | .320 | 8.000 | 146.000 | .958 |
| 8 | .035 | .001 | .999 | .030 | 3.000 | 74.000 | .993 |

H0 for Wilks test is that the correlations in the current and following rows are zero

Looking at the pairwise correlation table (Table-5), it can be deduced that all BENBIM variables have positive correlations with all EXPBIM variables. There is a considerable number of significant correlations can be seen.

**Table 5. Canonical correlation summary between BENBIM and EXPBIM variables.**

| Correlations[a] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | EXP BIM1 | EXP BIM2 | EXP BIM3 | EXP BIM4 | EXP BIM5 | EXP BIM6 | EXP BIM7 | EXP BIM8 | EXP BIM9 | EXPB IM10 |
| BEN BIM1 | Correl ation | 0.370 | 0.313 | 0.461 | 0.417 | 0.437 | 0.447 | 0.461 | 0.357 | 0.473 | 0.441 |
| | Sig. (2-tailed) | 0.000 | 0.004 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 |
| BEN BIM2 | Correl ation | 0.371 | 0.429 | 0.464 | 0.370 | 0.347 | 0.323 | 0.325 | 0.327 | 0.460 | 0.502 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.003 | 0.002 | 0.002 | 0.000 | 0.000 |
| BEN BIM3 | Correl ation | 0.369 | 0.459 | 0.484 | 0.490 | 0.384 | 0.399 | 0.548 | 0.369 | 0.425 | 0.502 |
| | Sig. (2-tailed) | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 |
| BEN BIM4 | Correl ation | 0.336 | 0.367 | 0.388 | 0.302 | 0.237 | 0.189 | 0.280 | 0.235 | 0.317 | 0.336 |
| | Sig. (2-tailed) | 0.002 | 0.001 | 0.000 | 0.005 | 0.029 | 0.084 | 0.009 | 0.031 | 0.003 | 0.002 |

In this paper only one pair is explained for its correlation and causation. As illustrated in Table-5, few large correlations exist as follows. They are also statistically significant at p=0.05. The largest correlation is between BENBIM3 – EXPBIM7 (rho- 548, positive). This means, reduction in the overall time, with less need for rework and early risk/ clash detection (BENBIM3) has a strong positive correlation with the ability of individuals who work with technology manage to perform their daily tasks more effectively (EXPBIM7). This correlation is merely an indication of the direction and the strength of a relationship. However, it does not indicate which variable impacts (or causes) what (Pallant, 2011). Since this paper also looks at the causation between two variable sets, a partial correlation analysis was also conducted to see if EXPBIM7 leads to (or possibly causes/ influences) BENBIM3. This would help addressing the research questions.

In partial correlation analysis, the correlation between dependent variables is studied first (i.e. BENBIM2 and BENBIM3). After that, it is tested whether there's a third variable (i.e. EXPBIM7) that has the ability to influence the correlation between those two original variables. If the third variable was successful in making a difference in the correlation between BENBIM variables, that means, the third variable (EXPBIM7) causes the existence of both BENBIM variables. The r-value between this third and two original variables are higher than the original r-value. Such a pattern of correlation is consistent and indeed suggestive of a third hypothesis, namely that EXPBIM7 has a strong causal influence on both BENBIM2 and BENBIM3 as shown in Figure 1 below.

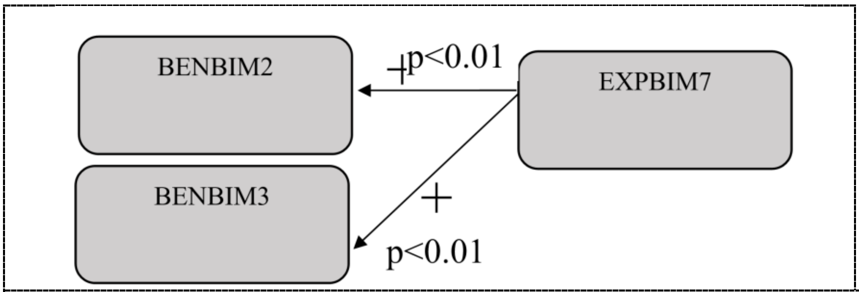


**Figure 1.** Correlation and causation between BIM benefits and BIM exploitation

In summary although only one causation is explained in this paper, it was deduced, the predictor variable set BIM benefits, secures a positive correlation with BIM exploitation being statistically significant at 0.01. This means higher the benefit accrual in BIM, the higher the level of BIM exploitation. When it comes to causation, it was discovered that 2 BIM benefits that were influenced/ caused the highest by BIM exploitation was BENBIM2 and BENBIM3.

**5. Conclusions and Further Research**

First, in addressing the question of 'what constitutes BIM exploitation in construction organisations?', it can be summarised that the ability to perform individual's daily tasks more effectively, the strategic leadership given from the senior management and the ability to operate more efficiently than before are the most significant aspects that constitutes to BIM exploitation at an organisational level. In response to the second research question, the benefits that had the highest accrual capability by exploiting BIM were: enabling better decisions through greater collaboration and ease of information abstraction through simulations and collaborated visualisation techniques. In response to the last research question, it was discovered that some BIM exploitation variables have the potential to influence or cause BIM benefits, but not all of them. They are: performing individuals' daily tasks more effectively and strategic leadership receiving from the senior management. The benefits that have the significant level realisation potential via latter exploitation means were, reduction in the overall time, and Ease of information abstraction. An interesting finding emerged from the analysis was that ease of information abstraction is one the benefits that had the highest potential to be realised by BIM exploitation. Interestingly, from the descriptive statistics, there was no significant differences found among the three categories of participants -senior, middle level and lower-level management in the way they have responded to BIM exploitation.

To sum-up it is seeming that there is a positive trend towards BIM use particularly for its beneficial use (i.e. exploitation) and there is a consensus of agreement from the industry that higher exploitation potentials lead to more BIM benefit realisations. This paper therefore recommends that continued practice of these exploitation streams could lead to greater BIM benefits. This paper only investigates few numbers of benefits, paving the path to future research avenues to investigate about all other available benefits and also to view exploitation in a different angle other than the enablers- results view.

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