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# Building Information Modelling at the Design Conceptual Phase and Effect on Project Quality and Budget: A Review

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## Abstract
Building Information Modelling is revolutionizing the workflow and processes in the industry and the design approach in creating building models. Among the stages of design, conceptualisation is being affected by BIM adoption as well. BIM has brought a lot of benefits to design but still designers are struggling to implement BIM at the very early stage of the design process. Thus, this study has been conducted to investigate how BIM is transforming concept design process and what could be the possible answer to overcome the barriers of BIM adoption at conceptualisation. From previous studies, the transformation of the design process within BIM methodology is explained and also general features of concept design stage are depicted to study its transformation within the evolution of Information Modelling. The study preferred reporting items for systematic reviews and Meta-Analyses (PRISMA) was used to identify inefficiency in construction design and conceptual phase, its effect on project quality and budget. To identify benefits and barriers to BIM at the design and conceptual phase this study presents preliminary findings based on twenty journal articles from an extensive review of a larger study. Findings from the review of the journal articles revealed the benefits and barriers to BIM at the design and conceptual phase and identify inefficiency in construction design and conceptual phase and its effects on project quality and budget.

## Keywords
Building information modelling, Design, conceptual phase, systematic review.

## 1. Introduction

The five leading causes of delay in construction projects, according to Alinaitwe et al. (2013), comprise scope change, payment delays, high cost of capital, poor monitoring and control and political insecurity and instability. An inadequate experience by the contractor, poor project planning, site management, and change orders was among the 15 leading causes of delay in Turkey, according to Alinaitwe et al. (2013), BIM offers the potential to address these challenges and improve construction industry performance. BIM is an innovative technology and process to virtually design and manage construction projects (Azhar, 2013).

BIM has been adopted in the construction sector over the last two decades and it has the capacity to transform and enhance performance by decreasing inefficiencies, improving productivity and increasing collaboration among project stakeholders (Abanda et al., 2018). Adoption of BIM offers the visualization of design, fast creation of alternative designs, automatic examination of model reliability, production of reports and building performance forecasting (Sacks et al., 2013). Despite the potential benefits of BIM, its implementation rate has been slow owing to various barriers (Walasek and Barszcz, 2017).

As in other countries, BIM is gaining the attention of South Africa construction practitioners. However, there are many challenges which affect BIM adoption in South Africa (Karafin et al.,2016). following Tuvi (2017), that there is a need to investigate the barriers to BIM adoption in the South Africa construction sector. Using the PRISMA methods based on twenty journal articles the study investigate how BIM is transforming concept design process and what could be the possible answer to overcome the barriers of BIM adoption at conceptualisation.

## 2. Methods

Systematic reviews are important in summarising the empirical evidence related to technology or method that helps in suggesting feasibilities for further research in the same area. Sometimes, contradiction or support of the hypothesis can be achieved through a systematic review. systematic review approach following Meta-Analyses (PRISMA) protocol to review a large number of refereed papers published between 2013 to 2021was adopted.

The systematic review has allowed us to gather all the relevant and valid information concerning implementing building information modelling at the design conceptual phase on project quality and budget. through its rigorous and well-defined approach that perform strict rules and a clearly defined protocol. It aims to limit systematic error (bias), mainly by attempting to identify, appraise, and synthesize all relevant studies by using a specific methodology (Wen and Gheisari, 2020).

### 2.1 Inclusion and exclusion criteria

**Inclusion criteria:**

The article should relate to BIM in design and conceptual phase.
The publication must have a transparent methodology.
The research must come from trusted publication outlets and must be journals in order to ensure rigour in the quality of examined literature.
The publication year of the papers must be published between 2013 to 2021
Paper had to be written in English.

**Exclusion criteria:**

The exclusion criteria were applied using the OR logical operator between them. The application of the search string in the Scopus database allowed us to generate 20 articles. We started the articles filtering phase by applying the inclusion criteria. We limited our field of study to journal articles published between 2013 to 2021 and written in English. Then, based on their title, keywords, abstract, and perhaps the full text, we have been able to select the articles that will allow us to answer the research questions. The exclusion process resulted in a total of twenty papers from the Scopus database.

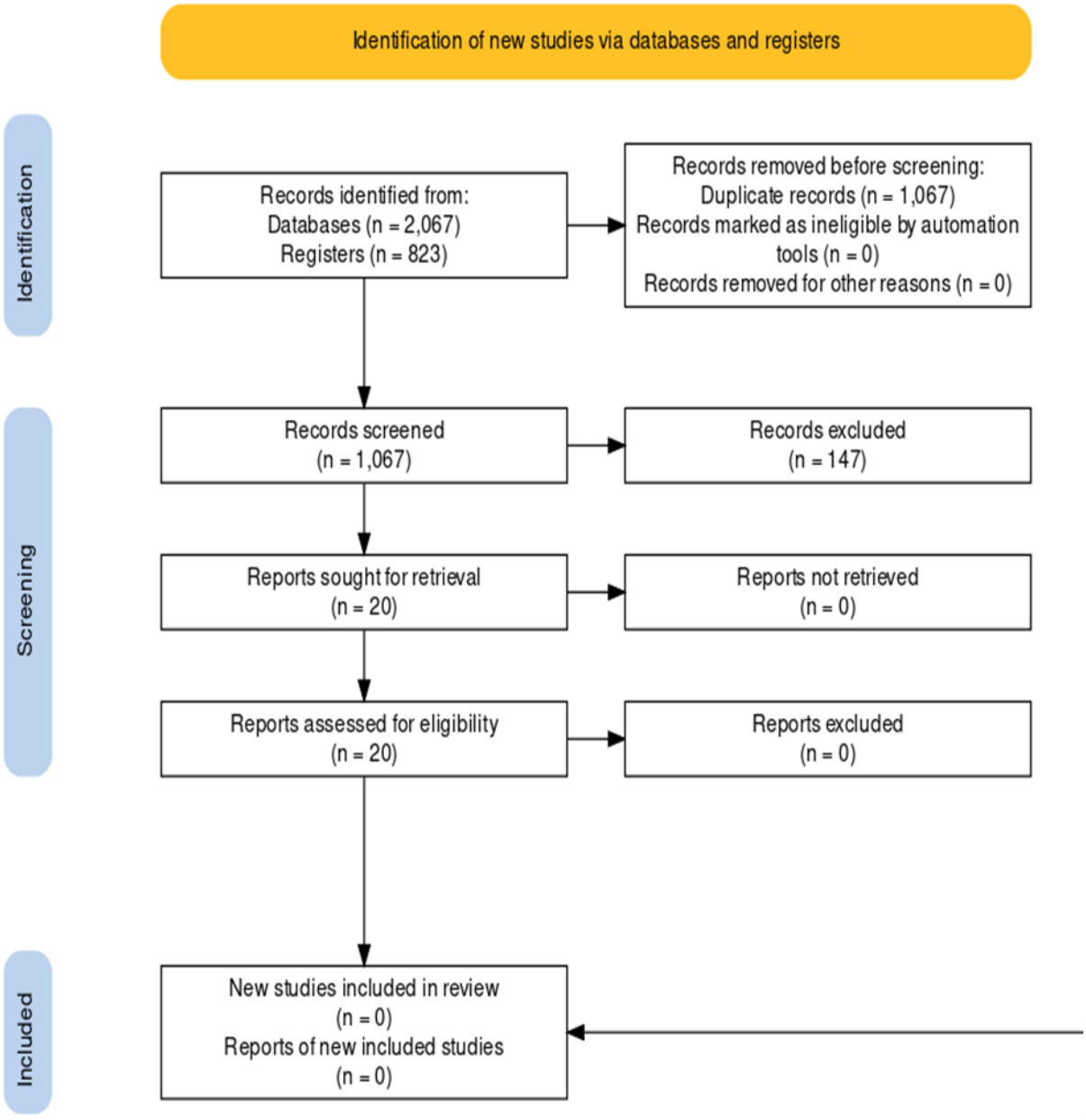
### 2.2 Selection: Research strategy

Through the Scopus digital libraries, we have done our search by using different methods with a specific configuration of the search string. Scopus is considered as the largest database of citations and abstracts from peer-reviewed bibliographies and quality websites and has a broad coverage of different disciplines and topics (Onososen and Musonda, 2022). It includes intelligent tools to track, analyse, and visualize searches (Saka and Chan, 2019).

**Table 1.** Systematic review process

| Database- SCOPUS | Database- SCOPUS |
|---|---|
| Criteria | Filters |
| Restriction | Topic (Title, abstract, keywords |
| Documents type | Article |
| Language | English |
| Years | 2013 to 2012 |

**2.3** Fig. 1. PRISMA flow diagram




## 3. Results

### 3.1 Results

Findings from the literatures related to the objectives depict that BIM is affecting how we formulate design solutions and changes the design process in three stages: conceptual design, construction documents and engineering services by providing earlier accurate visualisation, interrelated changes, accurate drawings and cost estimation from 3D model, improving collaboration and sustainable design. Besides, at concept design stage, sketching is a critical activity in achieving a creative solution and 3D modelling is a common expression of ideas. Architects most of the times review the options on aesthetics specifically at this stage. Besides, some digital design methods such as generative approach have introduced new ways of design to create more exotic and innovation shapes. When the concept is

finalised, the architect and the engineers start doing analysis looking into design possibilities to optimise the design. Early-stage analyses are not properly done because they are not fast and integrated to design. Findings from the literature regarding the actual benefits of BIM in conceptualization, BIM technology potentials and limitations and existing challenges will be further discussed in conjunction with the fieldwork's findings.

## 4. Discussion

**Table 33.** Barries to BIM Adoption

| Barries to BIM Adoption | Sources |
|---|---|
| High initial cost. | (Ismail et al.,2017) (Saka and Chan, 2020) |
| Lack of awareness about BIM benefits. | (latiffie et al.,2016) (Saka and Chan, 2020) |
| Legal issue. | (Bosch-Sijtsena et al.,2017) |
| Lack of BIM experts. | (McAuley et al.,2017) (Saka and Chan, 2020) |
| Data ownership issue. | (Park and Kim.,2017) (Enshassi et al.,2016) |
| Lack of standardized tools and protocols. | (McAuley et al.,2017) |
| Interoperability between software programs. | (Onososen and Musonda, 2022) |
| Insufficient governmental support. | (Onososen and Musonda, 2022) |
| Inadequate training on the use of BIM. | (Onososen and Musonda, 2022) |
| Absence of contractual requirement for BIM implementation. | (Ahmed et al.,2014) |

**Table 2.** BIM Benefits Through the Building Life Cycle

| Benefits of BIM use | Sources |
|---|---|
| Pre-construction: | |
| Enables faster and more accurate cost estimation. | (Khosrowshahi.,2017) |
| Resolve design clashes earlier through visualizing the model. | (Latiffi el al.,2016) |
| Better concept and feasibility. | (Eastman et al.,2016) |
| Effective design reviews leading to sustainable design. | (Khosrowshahi., 2017) |
| Construction: | |
| Reduce site congestion and improve health and safety. | (Khosrowshahi.,2017) |
| BIM allows better site utilization. | (Deshpande.,2014) |
| Improve planning of resources and sequencing alternatives. | (Enshassi et al.,2018) |
| Post construction: | |
| Makes asset management faster, more accurate and with more information. | Husain et al.,2014) |
| Ability to schedule and easy access to information during maintenance. | (Enshassi et al., 2018) |

**Table 3.** BIM Technology potentials & limitations from literature review

| BIM technology potentials | Sources |
|---|---|
| Sketch Up for solid modelling. | (Sketch Up, 2016) |
| PriMus for bills of quantities. | (ACCA, 2015) |
| BIM vision in Poland. | (Kogut P. 2015) |
| BIM Server as a platform to handle IFC data and open BIM for attribute data enrichment, related to building elements. | (Saygi et al. 2013) |
| Grasshopper 3D as a graphical algorithm editor integrated with | |

Rhino's 3D modelling tool. (Naboni &Paoletti 2015)

**Table 4**. BIM Adoption Rate in Various Countries

| Country | BIM adoption rate (year and sources) |
|---|---|
| Australia | 67%, 2016 (Red Stack BIM services, 2016) |
| Canada | 78%, 2018 (Macabe et al, 2018) |
| China | 67%, 2014 (Jin et al, 2015) |
| Denmark | 78%, 2016 (Malleson, 2016) |
| Estonia | 51%, 2015 (Usesoft AS,2016) |
| Japan | 46%, 2016 (Malleson, 2016) |
| Poland | 23%, 2015 (Juszczyk et al., 2015) |
| United Kingdom | 74%, 2018 (Malleson, 2018) |
| United State | 79%, 2015 (Gerges et al.,2017) |

**Table 5.** BIM digital objects

| Clusters | Description | Sources |
|---|---|---|
| Scan to BIM | BIM objects that can be monitored and retrieved via point cloud data via laser scanning and photogrammetry. | Adan et al. (2018) |
| Interoperability | BIM objects are discussed in the context of stakeholder information exchange interoperability. Research conducted developed a plethora of process maps to identify potential. BIM users and IER | Arayici et al. (2018) |
| Clash detection | Clash and error detection can be achieved using: i) visual representations and error detections (e.g. Solibri clash detection software). | Sabart (2018) |
| 3D printing and Additive manufacturing | The integration of 3D printing and BIM in manufacturing is a new area of research that has not been explored fully. | Goessens et al. (2018) |

## 5. Conclusions

This study looks into the impact of BIM in concept design stage. It has basically investigated the literatures on how BIM is transforming the general process of design and by pointing out features of concept design stage, it shows what specific requirements have not been met in conventional design process that will shift conceptualization toward adopting BIM. One major fact is that the need for integrated fast analysis to look into design possibilities and to help design decision-making process has not been fulfilled in traditional concept design. BIM is an answer to the inefficiencies of conventional processes and has brought a number of benefits to the design process making it more integrated and collaborative, however not all the areas of concept design is supported by the idea of information modelling and designers are still struggling to achieve a best conceptual design solution in a short time. Technology enhancement can be very helpful in this regard but other areas such as updated mind-sets, a proper methodology for

design and supports for a creative thinking process in concept design are as important as having an ideal collaborative technology in hand. Through this study, new exciting research opportunities have been found for future research. Ultimately, we encourage further work that could provide valuable information to practitioners and support new research and academic findings.

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