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Review

A Critical Review of Maturity Model Development in the Digitisation Era

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Abstract: Maturity models assess the prevailing capability level and proffer the necessary capabilities for effective adoption in a systematic roadmap. This is considered essential to achieve diffusion of the emerging technologies. The paper provides a guide to maturity model development in the digitisation era. This study adopted scientometrics and meta-synthesis to critically review and provide guidance on maturity model development. Firstly, bibliographic data was collected from the Scopus database and analysed using Scientometrics. Secondly, developed BIM maturity models were critically reviewed. The study identified areas of maturity model deployment and the industries of deployment. It also identified the present areas of deployment of maturity models. The second aspect critically reviewed selected BIM maturity models through stated parameters and outlined the necessary criteria for maturity model development. Maturity model is widely adopted to achieve optimisation and proper assessment in various industries. The study identified the industries where it is deployed and identified the areas of maturity model deployment in the digitisation era. In addition, it was observed that some existing BIM maturity models do not conform to the various requirements expected of a maturity model. The study is unique in the methods adopted to achieve its results. Also, it identified the areas of maturity model deployment. The study is helpful as it provides the criteria for maturity model development hereafter, while also helping BIM users choose among the existing BIM maturity models. The study is crucial for proper maturity model development in the digitisation era.

Keywords: BIM; construction digitisation; maturity model development; metasynthesis; scientometrics; roadmap

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1. Introduction

A maturity model is a structured collection of elements that describe the characteristics of an effective process [1]; it describes the pathway for organisational improvements [2]. Maturity models can also be said to be the collation of process maturity levels from the starting point (immaturity) to highly mature [3]. Maturity models are designed as an assessment tool that is employed to access the competence or effective level of a system and proffer the needed solution by identifying the capabilities required to attain optimal effectiveness. Maturity models are usually systematic and are step-wise. They can be referred to as improvement tools to achieve a competitive advantage.

Maturity models are generally defined by capability levels. A capability level is a well-defined evolutionary plateau describing the organisation's capability relative to a particular process area [1]. It refers to an organisation's achievement of process improvement at each process area [4]. Capability levels are cumulative. Thus, a level needs to be achieved before going to the next; it is systematic and stratified.

The development of maturity models has experienced a surge since the success of the Capability Maturity Model (CMM). Maturity models are developed to provide a framework for the achievement of excellence through a systematic, stepwise framework. This framework assesses the current state and offers the necessary guidelines required for improvement to achieve a higher level of performance. Maturity models are non-restrictive and can be developed for any process or organisational space that requires improvement. They have been applied to innovation, business process, new product development, project management, supply chain management, and people capability, among others.

Researchers have adopted maturity-based approaches in developing performance improvement frameworks: maturity models and maturity grids. Two prominent maturity frameworks that deployed these approaches are CMMI (maturity model) [1] and Crosby's Quality Management Maturity Grid (QMMG) (this adopted a maturity grid approach). Although the approaches might differ, both are employed to assess and improve processes. Both approaches also deploy maturity levels and process areas, but the mode of presentation is one of the key differences. However, according to [5], maturity grids are preferred by companies because they are cost-effective and time-saving. However, they have not gained as much popularity as maturity models, especially in academia. The differences between them are as stated in Table 1. It is worth mentioning that maturity assessment in the construction industry has been through maturity models. None has applied the maturity grid approach.

Table 1. Difference between maturity grid and maturity model [5,6].

S/N	Aspects	Maturity Grid	Maturity Model
1	Orientation	This applies to companies in an industry; it is company-focused	It is process specific
2	Mode of assessment	The structure shows levels of maturity against KPIs of performance in a cell. These cells normally contain descriptions in text form describing the required performance per level.	Assessment is done by: i. Likert or binary yes/no questionnaires ii. Checklist to assess the performance
3	Intent	They are less complex.	They are a more complex assessment tool and they follow an internationally recognised standard format.

Maturity models are usually developed to be in stages, or stepwise, in their deployment. This is because they provide a continuous framework whereby the achievement of a level is a prerequisite to the next, as the outputs on that level serve as the input for the next. This was supported by the stage theory of [7]. The work tested stages of growth of technological ventures based on a four-stage model. It posits that each stage of growth contributes to higher growth rates. It further says that problems occur sequentially and define the next stage that the business must pass through to achieve viability. Simply put, the growth rate depends on the match between stages and the structure.

The works of [8,9] provided the major phases and the key elements required in designing a maturity model. Becker and Knackstedt posited that the criteria for the development of maturity models are:

i. Comparison with existing maturity models
ii. Iterative procedure
iii. Evaluation
iv. Multi-methodological procedure
v. Identification of problem relevance to be solved by the model
vi. Problem identification in terms of the application domain, conditions for its application and the benefits
vii. Presentation of results

viii. Scientific documentation: this details the entire process and parties involved in the development of the maturity model. De Bruin identified the phases for the development of maturity models as:

i. Definition of scope
ii. Determination of design for the model
iii. Determination of domain components to be measured (Populate)
iv. Test for validity, reliability of developed maturity model
v. Deploy: This is the availability of the model for use to parties independent of the development of the model.

These two studies can be employed in the comparative analysis of maturity models, and were therefore adopted for this study. To this end, this study employed these criteria in the comparative analysis of selected existing BIM maturity models in the construction industry. The study reviews some existing maturity models developed between 2010 and 2019. The study adopted a selective data selection approach whereby the popularity of some of these models based on the literature, among other criteria, was employed as the yardstick for inclusion. Some tools missing from the study by [10] are reviewed in this study as the table is not exhaustive. This study discussed the strengths and weaknesses of the maturity models by adopting the criteria for maturity model developments by [8,9]. These studies identified the contents and phases required to develop maturity models. Thus, the specific objectives of this study are:

(1) Identify various areas of maturity model deployment
(2) Perform a review and comparative analysis of existing BIM maturity models between 2010–2019
(3) Examine selected maturity models through the lens of two selected studies
(4) Provide a guide on the development of maturity models

2. Research Methodology

Adopting technology, innovation, or process improvement has been a herculean task for many sectors and organisations alike. This is because many adopters are often confused about how to manoeuvre and achieve maturity as regards adoption. Moreover, they are confused on how to integrate the new innovation into their existing workflow. Thus, maturity models were developed as a pathway to help organisations and industries.

The study adopted a two-pronged pathway to achieving its objectives: (1) Identify various areas of maturity model deployment. (2) Perform a review and comparative analysis of existing BIM maturity models between 2010–2019. (3) Examine these maturity models through the lens of two selected studies. (4) Provide a guide on the development of maturity models. These objectives were achieved through scientometrics and meta-synthesis.

2.1. Scientometrics

The first objective involves the identification of the areas of maturity model deployment. This was achieved by carefully searching the Scopus research database with the following keywords: maturity model and maturity model development. The result returned a total of 5045 results; this was further restricted to only journal articles. Articles were adopted for the study because they are considered to undergo a more rigorous and meticulous scientific process before publication. This returned a total of 1926 documents. The bibliographic data collected was analysed using a visualisation tool, Vosviewer [11]; this has been adopted in several studies [12–16]. The adoption of this method of analysis provides a visual result through the mapping of the relationship between items. Items are grouped into clusters. Figure 1 presents the mapping of the various areas of maturity model deployment.

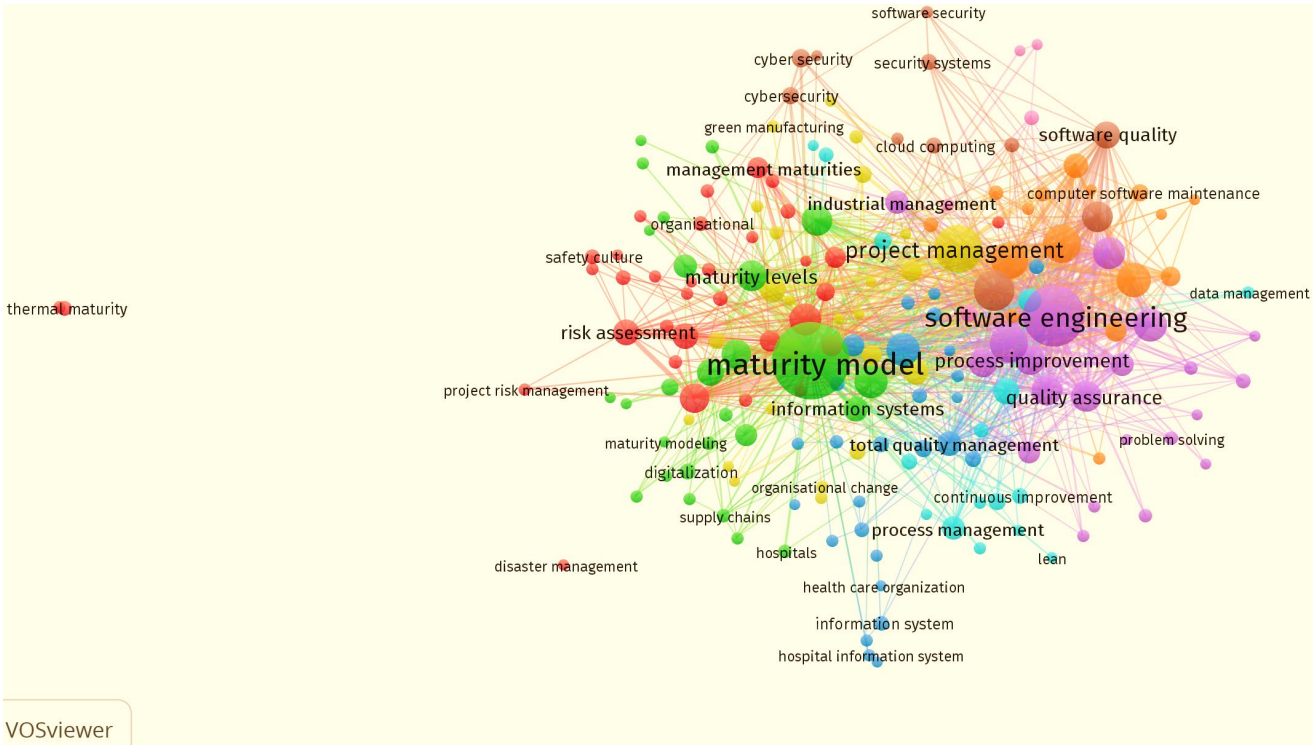

Figure 1. Areas of maturity model deployment.

Results reveal that the maturity model has been applied in different sectors (Table 2). In the main, maturity models have been employed to provide a roadmap to better or higher levels of efficiency and productivity. In addition, they have been seen as problem-solving and optimisation tools. They also help with monitoring and accurate process assessment. A properly developed and implemented maturity model provides a matured and optimised system under focus through a systematic optimisation approach. It is evident that this is well known, considering the number of systems, processes and sectors where it has been adopted to achieve optimisation.

The study performed a year-based visualization to identify the recent areas where the maturity model has been adopted to achieve optimisation (Figure 2). It was observed that recently (from 2020) maturity models have been developed in the following areas to achieve process optimisation and maturity: BIM, smart city, IoT, green manufacturing, cyber security, network security, industry 4.0, smart manufacturing, digital transformation, digital maturity, digitilisation, e-health, and disaster management. It is evident that the efforts to achieve a matured diffusion of new technologies and digitisation has been enhanced through the deployment of the maturity model. The maturity model is thus believed to be a silver bullet to achieving step-wise process optimisation.

The study performed a visualisation based on years to identify the recent areas where maturity model has been adopted to achieve optimisation (Figure 2). The figure provides the various elements in clusters and different colours, with a year bar on the bottom identifying the years as against the colour of items in the cluster. It was observed that lately (from 2020) maturity models have been developed in the following areas to achieve process optimisation and maturity: BIM, smart city, IoT, green manufacturing, cyber security, network security, industry 4.0, smart manufacturing, digital transformation, digital maturity, digitalisation, digiti, e-health, and disaster management. It is evident that the efforts to achieve a matured diffusion of new technologies and digitisation have been enhanced through the deployment of the maturity model. The maturity model is thus believed to be a silver bullet to achieving step-wise process optimisation.

Table 2. Application of maturity model.

S/N	Areas of Deployment	Industry or Sectors	Application
1	Building information modelling, artificial intelligence, disaster management, energy efficiency, energy management, enterprise risk management, Internet of Things, knowledge-based system, risk assessment, risk management, safety culture, smart city, thermal maturity, waste management	Construction industry, automotive industry, public governance, health care, ICT, manufacturing	Capability assessment, decision making, decision support system, maturity assessment, management maturities, roadmap, maturity levels, optimisation, problem-solving, process improvement, process monitoring, strategic planning, quality management, process assessment
2	Communication technology, digital maturity, digital technologies, digital transformation, e-government, government data process, information management, industry 4.0, information systems, information security, information technology, logistics 4.0, operations management, procurement, smart manufacturing, supply chain, supply chain management, technology adoption		
3	Customer satisfaction, crisis management, health care delivery, e-health, hospital information system, human resource management, knowledge management, natural resource management, organisational culture, organisational maturity, resource allocation, total quality management		
4	City resilience, climate change, competitive advantage, environmental sustainability, green computing, new product development, organisation change, organisational capabilities, project management, strategic, sustainable development		
5	Computer software, lean production, process engineering		
6	Business process management, business-IT alignment, change management, data management, IT governance		
7	Dynamic capabilities, software industry, software process capability		
8	Cloud computing, cyber security, product lifecycle management, technology transfer		

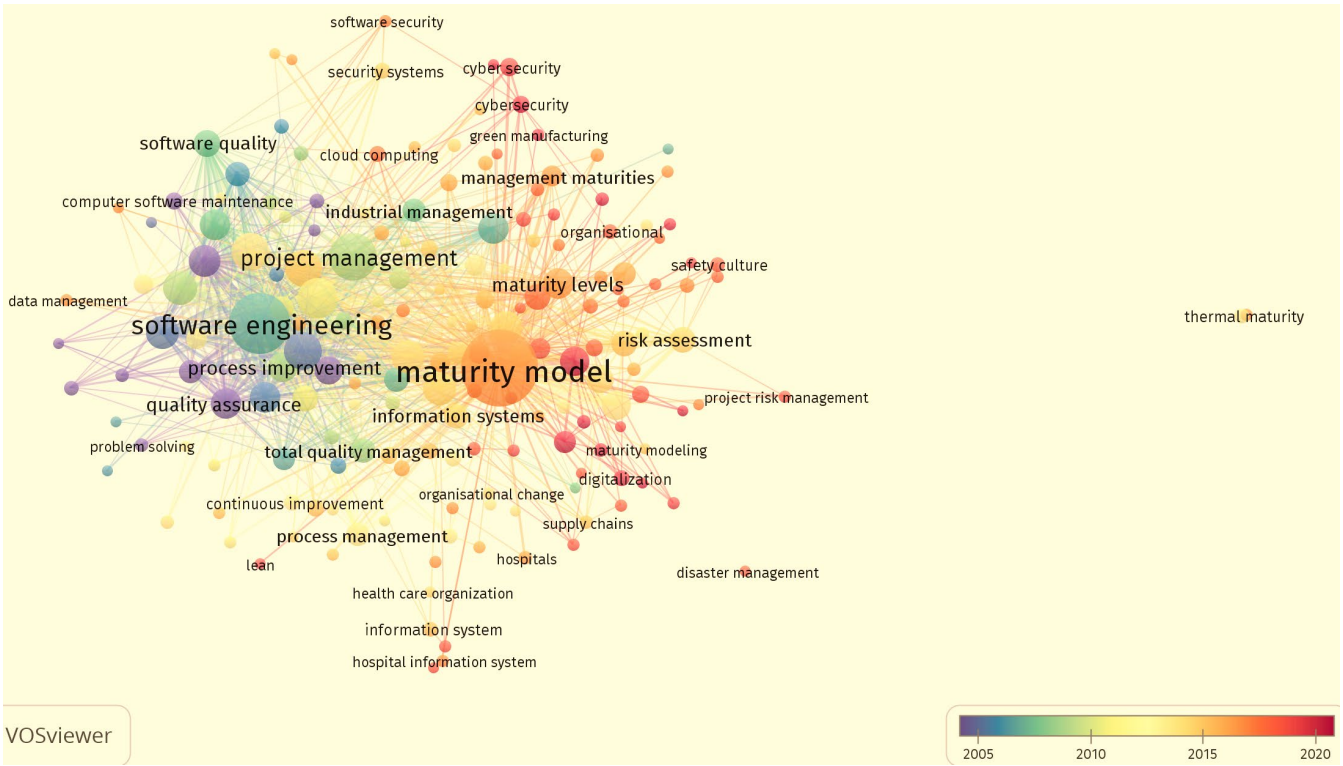

Figure 2. Overlay visualisation based on year.

2.2. Meta-Synthesis

Meta-synthesis has been adopted in various studies to gain deeper insights and understanding of the phenomenon under study in different studies [17,18]. It permits the critical review and synthesis of existing studies to develop new conceptual frameworks.

2.2.1. Analysis of the Models

The content of the selected models was discussed in a systematic format in order to achieve a critical analysis. Two studies were adopted in this regard. These maturity models were examined through the lens of the study by [8,9]. The maturity model development criteria proposed by these studies were examined. Afterward, this study performed an analysis of the maturity models under six headings derived from the combined criteria from these studies.

2.2.2. Maturity Model Selection Benchmarks

The study adopted a data selection approach whereby the selection of reviewed models was based on some specific eligibility criteria. The reviewed BIM maturity models were selected out of many that have been developed, because most of the existing maturity models are repetitive in nature. Moreover, some of the widely acclaimed maturity models are not referred to as such by some researchers. For instance, Ref. [19] opined that BIM3 and the UK BIM wedge are the most widely referenced BIM models. Thus, this study did not include the BEW Richards BIM maturity model in the review; it is not deemed a maturity model because it does not fulfill all the requirements for a maturity model.

This study provides a review and comparative analysis of these selected BIM maturity models. The reviewed BIM maturity models are BIM CAREM, BIM3, VDC scorecard, BIM quickscan, organizational BIM assessment profile, and multifunctional BIM maturity model. The selected BIM maturity models are not exhaustive and were selected based on the following criteria: their popularity, availability of literature on their result, not developed by a software developer, and containing domains as expected of a maturity model. These models were developed between 2010 and 2019.

3. BIM Maturity Tools and Models

Several frameworks have been developed to assess and improve BIM maturity in several organisations and projects. These models were developed suited to the construction environment where they were intended to be applied. Hence, different yardsticks and designs were adopted. Some of these BIM maturity models are reviewed below.

There are diverse BIM maturity tools and models in the construction industry. Some tools missing from Table 3, as adapted from [10], are reviewed in this study as the table is not exhaustive.

Table 3. BIM maturity: tools and methods (Adapted from Ref. [10]).

Tool	Owner	Type	Application
BIM Excellence Online Platform	Change Agents AEC	Maturity tool	Organisation, Project
BIM Online Maturity Assessment	National Federation of Builders (NFB)/CITB	Maturity tool	Organisation
BIM Supporters' BIM Compass	BIM Supporters	Maturity tool	Organisation
CPIx BIM Assessment Form	Construction Project Information Committee	Maturity tool	Organisation
Maturity Matrix: Self-Assessment Questionnaire	Project 13—Institute of Civil Engineers	Maturity tool	Organisation
NBIMS Capability Maturity Model	National Institute of Building Sciences	Maturity tool	Organisation
Organisational BIM Assessment	Pennsylvania State University	Maturity tool	Organisation
SFT's BIM Compass	Scottish Futures Trust	Maturity tool	Organisation
Supply Chain BIM Capability Assessment	Wates	Maturity tool	Organisation

Table 3. *Cont.*

Tool	Owner	Type	Application
Vico BIM Scorecard	Vico Software (now part of Trimble)	Maturity tool	Organisation
BIM Maturity Assessment Tool (BMAT)	University of Cambridge	Maturity tool	Project
BIM Maturity Measure	ARUP/Institute of Civil Engineers	Maturity tool	Project
BIM Working Group BMAT	Public Sector Working Group	Maturity tool	Project
Dstl BIM Maturity Assessment Tool	Dstl	Maturity tool	Project
VDC Scorecard	Centre for Integrated Facility Engineers, Stanford University	Maturity tool	Project
BIM capability assessment reference model	[20]	Capability assessment tool	Projects(facility)
Owner's BIMCAT (Competency Assessment Tool)	Giel & Issa (2014)	Maturity method	Organisation
BIM Maturity Assessment Tool	Department for Transport	Maturity method	Organisation
Building Information Modeling Cloud Score (BIMCS)	Du et al. (2014)	Maturity method	Organisation
Organisational BIM Assessment Profile	Pennsylvania State University	Maturity method	Organisation
BIM Return on Investment Tool	Scottish Futures Trust	Benefits tool	Projects
BIM Value	NATSpec	Benefits tool	Organisation, Projects
BIM Benefits	University of Cambridge	Benefits tool	Projects
BIM Level 2 Benefits Management	PricewaterhouseCoopers Strategy	Benefits method	Projects
TfL BIM Benefits Management Strategy	Transport for London	Benefits method	Projects
ROI Analysis	Giel & Issa (2013)	Benefits method	Organisation

4. Selected BIM Maturity Models

4.1. BIM Capability Assessment Reference Model (CAREM)

This maturity model was developed by [20,21] and seems to be the latest in the published works on BIM maturity models. Its development is deeply rooted in the meta-model of the ISO/IEC 330xx family. It employed a 4-point rating scale. The purpose was to develop a BIM maturity model suitable to enable BIM assessment of the AEC/FM processes of the facility life cycle phases. It was updated iteratively through expert reviews and an explanatory case study. According to [20], it consists of two parts, the BIM PRM (comprises definition of AEC/FM processes, notably process purpose, base practice, process outcomes and work products) and BIM MF. On the other hand, BIM MF enables BIM capability assessment by including a schema comprising BIM capability levels, associated BIM attributes, and a rating scale [21].

4.2. BIM Maturity Model (BIM3)

The building information modelling maturity matrix (BIM3) was developed by Succar [3]. It is one of the most cited BIM models [19]. It was developed to assess individual/team competency organisational capability.

BIM3 is flexible and can be employed by organisations, or projects. According to [22], it was developed to overcome the deficiencies in NBIS BIM and BIM proficiency matrix. Due to this, this study did not discuss them. These two were criticized for high subjectivity, limited measurement scope in technical aspects, and inadequate reliability and consistency [23]. BIM3 has three main process areas and a five-level scale. Although it was adjudged to be flexible, [22] opined that it lacks a user guide and, thus, its applicability is reduced. It is noteworthy that the BIM3 has undergone several improvements since it was first developed and is continuously tested in organisations and countries.

BIM3 is considered to be comprehensive compared to the models before it but regarded to be weak in the aspects of information management [24]. This highlighted weakness is the main crux of BIM adoption and usage [25]. Succar's work is also based on the CMM. Its five identified stages are Ad-hoc, Defined, Managed, Integrated, and Optimised. The maturity levels are a reflection of the extent of BIM abilities, outcomes, and requirements as opposed to minimum abilities represented by capability stages [3].

4.3. BIM Quickscan

This maturity model was developed by [26]. It was launched in Holland in 2011 according to [22], but [26] claimed it was created in 2009. It is a BIM benchmarking tool for companies, and it employed both qualitative and quantitative assessments. It was built for and tested in the Netherlands.

It has been employed by both individuals and companies, both within companies and online. It was not designed originally to assess individuals (consultants) [26]. It employed four areas or chapters and had 44 questions.

4.4. Organisational BIM Assessment Profile

This BIM assessment profile was created by Pennsylvania State University computer integrated construction (CIC) [27]. It provides a guide for facility owners, but the focus is on organisational BIM assessment. It comprises 20 measures and six maturity levels. However, its use in the AEC/FM industry is incomplete [20].

4.5. VDC BIM Scorecard

Virtual and design construction (VDC) scorecard was created at Stanford University. It was developed in 2009 and revised in 2011 [28] but [22] claimed it was developed in 2012. The purpose was to provide a holistic, practical, and adaptive approach to BIM evaluation. The scoring used by the VDC scorecard covers four major areas of VDC, which are Planning, Adoption, Technology, and Performance [29]. It has 27 questions and employed five capability levels. According to [29], VDC has ten divisions, fifty-six measures, and the confidence level measured by seven factors to assess maturity while assessing the maturity of BIM implementation on projects. The tool has several distinct features, such as the establishment of confidence level, which analyses input data and quantitative measurements of the degree of objective compliance [22]. However, assessing the achievements of performance targets in a progressive manner is difficult due to the large number of quantitative and qualitative measures employed [10].

4.6. Multifunctional BIM Maturity Model

The Multifunctional BIM maturity model was developed by [30]. It was developed in Asia with a focus on the Hong Kong and mainland China experts providing the required feedback at the Delphi and interview stage. It has three domains and 21 subdomains and 4 (0–3) maturity levels (stages). It focuses on the domains of technology, process and protocol. It was developed to evaluate BIM maturity in projects, companies and the industry. Other details such as validation methods are not clearly defined; thus, there is limited information about this BIM maturity model.

5. Findings and Discussion

5.1. Development of BIM Maturity Models

As earlier mentioned, this study adopted the criteria proposed in the works of [8,9] to discuss the selected BIM maturity models; the two sets of criteria were combined and employed under the following headings: scope, design, development of constructs and validation, deployment and evaluation, presentation of results, and systematic documentation.

5.2. Scope

The scope of a maturity model refers to the focus of the model. This is the first step as it shapes and determines the remaining phases of the model, including its use and benefits. To achieve it, a researcher must review existing models and carve a niche for the newly proposed model. To successfully define the scope, the reason and relevance of the model must be defined clearly. According to [9], maturity models can either be domain-specific or general in terms of their scope.

Generally, existing BIM maturity models are either project focused, or organisation focused. The reviewed BIM maturity models for this study are not any different (Table 4). When defining the scope, the researcher must define the model's actual purpose, which necessitated its development. For instance, BIM CAREM is developed for the AEC industry's facility management process. It is rooted in a standard. This clear scope informed its development in relation to existing BIM maturity models. Although BIM3 is one of the most widely referenced, its focus and development are different from BIM CAREM.

5.3. Design

The design phase of a maturity model entails determining the architecture. This includes the audience, method, and driver of application, respondents and application [9]. This phase also includes defining and mapping the iterative procedures and the choice of the scientific methodological procedure as outlined in [8]. The capability levels and nomenclature are defined and chosen to serve the purpose for which the model was developed, according to the structuration theory. Different maturity models adopt different designs tailored to achieve the scope.

The BIM maturity model space includes many developers, including software manufacturers, academicians, and others. Hence, for diverse reasons that might include competitive advantage and the non-iterative method employed in developing maturity models, most maturity models failed to publish their design method. The BIM CAREM design was well documented [20,21]. However, this study did not find documented evidence for the design of BIM3.

5.4. Development of Constructs and Validation

This is the third phase after the definition of scope and design for the proposed model [9]. This phase defines what needs to be considered and how it will be measured during the maturity assessment to achieve full maturity [9]. These comprise the critical success factors or capabilities or dimension areas required to be satisfied to achieve maturity. Domains and their components necessary for maturity assessment can be achieved through an extensive literature review. These constructs are gotten from the literature and tested through a multimethodological approach. Most maturity models apply qualitative (interview, Delphi techniques, nominal group study, case study, among others) and quantitative (questionnaire) methods. The second phase in the approach is usually adopted to confirm the derived constructs from the first stage. The first stage using the qualitative method can be conducted more than once to achieve tangible convergence among opinion experts. The choice of method is hinged on many factors, including available resources, the type of respondents, and the prevailing industry environment, among other constraints observed by the researcher. The data generated are analysed and validated using statistical tools such as factor analysis and structural equation modelling, depending on the study; this is central to the development of the maturity model [9]. Table 5 outlines the different

domain components identified by the reviewed BIM maturity models. The methodological approach employed by the different BIM maturity models reviewed is presented in Table 4.

5.5. Presentation of Result

This is the publication of the maturity model after the development in a medium that is accessible to the intended audience [8]. This is imperative in communicating the developed results and making it available to the intended audience; according to [31], these audiences are technology and management-oriented. In this study, all reviewed BIM maturity model published the maturity models to the intended audience.

5.6. Deployment and Evaluation

This is the verification of the developed model in order to test its suitability for the purpose. It should be deployed to entities that are independent of the study in order to test its standardisation and generalizability [9]. According to [31], the developed model can be evaluated to test for the following: functionality, completeness, consistency, accuracy, performance, reliability, usability, fit with the organisation and other variables. A maturity model is considered adequate when it is fit for the problem it was designed to solve. The process of testing the model is rigorous and balanced enough to be considered adequate to test the suitability of the developed model. For BIM maturity models, they must be deployed and evaluated in the industry. The developed maturity level is also flexible in its design to track and accommodate time-based development in the field. This was termed as "maintain" by [9]. A typical example of a BIM maturity that has exhibited this is Succar's BIM3. Over time, it has seen many developments to accommodate the different developments in the BIM adoption field. Most BIM maturity models have online assessments where users can assess their maturity; however, it should be noted that most are commercialized.

5.7. Systematic Documentation

This should not be confused with the presentation of the result. Systematic documentation is the communication of the entire maturity model development process. It documents the process and all other factors necessary for the development of the maturity model in a systematic sequence that another researcher can easily reproduce. This documentation must be detailed, and well-articulated, highlighting the parties involved, applied methods, and the results [9]. This can be through scientific publications, journal publications, conferences, and dissertations among others. Most BIM maturity models failed in this aspect; most published the models but not scientific documentation of the development process of the maturity model.

Table 4. Comparative analysis of selected BIM maturity models.

Element / Element	BIM CAREM [20]	BIM3 (Succar, 2010)	BIM Quickscan [26]	Organisational BIM Assessment Profile [27]	VDC BIM Scorecard [32]	Multifunctional BIM Maturity Mod323el [30]
Scope	Develop a formal BIM capability assessment framework for the AEC/FM process	To assess individual/team competency organisational capability	Model for the Netherlands	To assess organisation maturity of BIM, for building owners	The purpose was to provide a holistic, practical and adaptive approach to BIM evaluation on projects	To assess BIM maturity in projects, companies and the industry.
Focus	AEC/FM	AEC/FM	AEC/FM	AEC/FM	AEC/FM	AEC/FM
Analysis dimensions	Organizations	Organization	Organization	Organization	Projects	Industry, organization, projects
Domains/Process area	Process, technology, organisations, human aspect, BIM standard	Process. People, technology	Organisation and management, mentality and culture, information structure and information flow, tools and application	Strategy, use, process, information, infrastructure, personnel	Portfolio and project management, cost planning, cost control, schedule planning, production control, coordination, design team management	Technology, process, protocol
Maturity levels	4(0-3)	5	6	6	5	4
Inspiring framework	ISO/IEC 330xx family	CMM				
Assessment method/test	Exploratory case study, expert review	Not clear but provides online assessments	Pilot projects, expert review, statistical tests	Not defined	Pilot projects, user interviews, expert reviews, statistical tests	Not clearly stated
Maturity levels	Incomplete BIM Performed BIM Integrated BIM Optimized BIM	Initial Defined Managed Integrated Optimized	0 to 5	Non-existent Initial Managed Defined Quantitatively managed Optimising	Conventional practice Typical practice Advanced practice Best practice Innovative practice	Stage 0 Stage 1 Stage 2 Stage 3

Table 5. Comparative analysis of selected BIM maturity models variables.

Process Areas		Existing BIM Maturity Models					
		BIM CAREM	BIM3	BIM Quickscan	Organisational BIM Assessment Profile	VICO BIM Scorecard	Multifunctional BIM Maturity Model
1	Process	√	√		√		
4	Technology	√	√				
5	Tools and application			√			
6	Infrastructure				√		
7	Use						
8	Organisations	√					

Table 5. *Cont.*

	Process Areas	Existing BIM Maturity Models					
		BIM CAREM	**BIM3**	**BIM Quickscan**	**Organisational BIM Assessment Profile**	**VICO BIM Scorecard**	**Multifunctional BIM Maturity Model**
9	Portfolio and project management					√	
10	Production control					√	
11	Organisation and management			√			
13	Design team management					√	
14	Information structure and information flow			√			
16	BIM standard	√					
17	Information				√		
18	Construction data						√
19	As-Built modelling						√
20	FM data richness						√
21	Human aspect	√					
22	Cost control					√	
23	Cost planning					√	
26	Coordination					√	
27	Schedule planning					√	
29	Personnel				√		
31	People		√				
32	Mentality and culture			√			
33	Physical accuracy of the model						
34	IPD methodology						
35	Calculation mentality						
36	Location awareness						

6. Conclusions

To be digitally matured, organisations, industries, and actors must migrate from the level of traditional, non-digital processes to a completely digitally aligned work process. Achieving maturity in the digital era is very important as most technologies are collaborative in nature, and hence a wider and faster diffusion of information is critical. Efforts must be concentrated towards achieving full maturity systematically. A proven way of developing a systematic roadmap to achieving full maturity is developing and adopting a maturity model. Thus, the primary rationale for developing a maturity model is to assist stakeholders in achieving digital maturity through a systematic and stepwise approach. It provides the different maturity levels and the required steps necessary to achieve it.

This study reviewed maturity model development using scientometrics and meta-synthesis. The study observed that the maturity model had been adopted extensively in different sectors to achieve optimisation and as a problem-solving tool. Furthermore, it has been lately adopted for attaining maturity in the adoption of new and emerging technologies in the digitalisation era. However, a faulty development might not yield the desired result of a maturity model; hence the proper development of maturity models is critical (Figure 3). The study reviewed some BIM maturity models and analysed them using meta-synthesis against some maturity model development models. A comprehensive review and comparison of selected existing BIM maturity models was also presented; including the distinct features of the existing models, their shortcomings and domains, among others. The study found that most existing BIM maturity models did not satisfy the guidelines required for the development of maturity models.

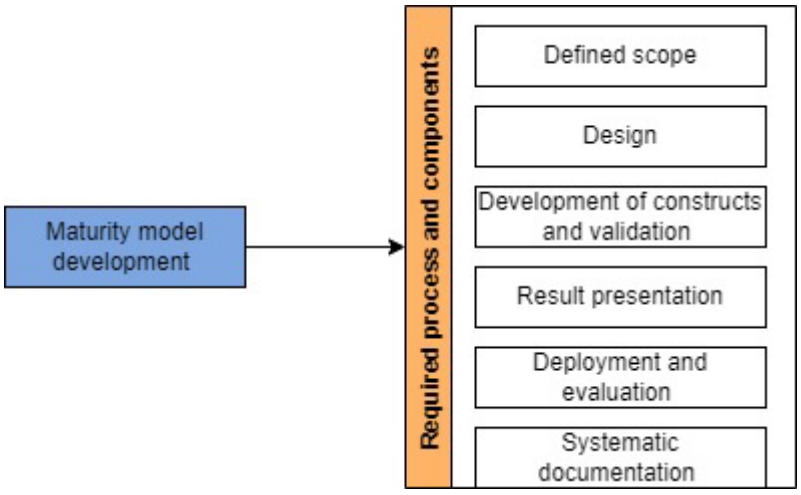

Figure 3. Components of maturity model development.

The study observed that most maturity models developed to date did not follow a verifiable approach, and were developed as the researchers chose. However, while maturity models were designed to respond to the context, the necessary aspects must be satisfied in their development. In addition, maturity models should be developed and tested practically beyond the theoretical development phases. The process of development should be articulate and be scientific.

Furthermore, building on the three studies highlighted provides the required stages and constituents for BIM maturity model development and maturity development in the construction industry. The study identified and discussed these outlines as scope, design, development of constructs and validation, deployment and evaluation, presentation of results, and systematic documentation. The paper offers a guide to the development of BIM maturity models and can be adopted in developing maturity models in the construction industry. It provides a scientific and replicable methodology for maturity model development. Furthermore, it provides a uniform development basis while allowing individual

models to achieve their intended purpose. The study's limitation is the restriction to the number of reviewed models based on the selection criteria.

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