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KEY ATTRIBUTES OF CONSTRUCTION MATURITY MODELS: A SYSTEMATIC REVIEW

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ABSTRACT

Maturity Models assist organisations to evaluate their existing capabilities. A key component of a maturity model is its attributes which govern the assessing criteria of the model. Several construction maturity models exist in various platforms, however, there seems a noticeable gap in the literature on existing maturity model attributes and a model template for construction sector. Therefore, to fill that gap, this study aimed at reviewing the existing construction maturity model attributes. PRISMA literature review technique was adopted to systematically review the existing, construction related maturity model attributes. The identified attributes were analysed using thematic analysis method. The study used twenty prominent construction maturity models to identify their key attributes. These attributes were analysed, and 13 key themes were derived that described model attributes. This study summarised all the literature findings on significant existing model attributes and established the foundation on how to derive attributes relevant to construction maturity models. Further, this study adds to the body of knowledge on construction maturity model attributes and opens up avenues to develop more robust maturity models. This study contributes to the practice by encouraging the use of maturity models and attributes to enhance the existing maturity of construction firms. The results of this study can be directly used by industry practitioners to establish best practices within the construction projects. Further research is encouraged on identifying additional components of models and testing the effectiveness of the findings with empirical data in future studies.

Keywords: *Construction Maturity Models; Model Attributes; Model Components PRISMA; Systematic Review.*

1. INTRODUCTION

With continued challenges within the construction industry, there was a need to assess industry practices to identify their effectiveness (Htoo et al., 2023; Maske & Valunjkar, 2020). Many efforts have been made by academics and professionals in the construction field to measure and enhance performance. Most of these activities have resulted in the

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creation and application of frameworks and models for performance assessment that concentrate on organisational and project levels (Willis & Rankin, 2012). Eventually construction industry inclined to use Maturity Models (MM) as a tool to enhance the organisational and project capabilities to mitigate the issues that hinder effective project completion (Khoshgoftar & Osman, 2009). MMs were initially developed targeting the software industry in the United States and with the success, it expanded to many other industries. Capability Maturity Model (CMM) is a prominent MM that is considered a catalyst and many models were later developed adopting various aspects of CMM as a foundation (Brotby, 2009). Similarly, with this development many maturity models were later developed specifically targeting the construction industry (Sun et al., 2009).

There are several types of MMs extended to various areas within the broad spectrum of construction such as project management, construction management, risk management, process management, change management etc. (Khoshgoftar & Osman, 2009; Bąk and Jedynak, 2023; Nowotarski et al., 2016). A key component of all these models is the model attributes which act as the criteria that governs the maturity assessing process (Silva et al., 2021). These attributes act as the measuring apparatus of the models and provides distinctive guidelines on various construction related aspects (Jayanetti et al., 2022). However, scrutinising the existing models, less evidence is available on a comprehensive review on model attributes which provide a template or a conceptual model for construction MMs. Even though few models have elaborated upon certain attributes, there is a dearth in literature on a holistic and an explanatory study. The existing studies do not provide a detailed discussion on model attributes, relationships and do not synthesise and summarise the key findings. The theories on MMs have saturated over the years reducing novel studies. Moreover, the existing studies do not consider the key themes among the model attributes and fail to provide details on their regularity. Therefore, this study is aimed at reviewing the attributes of the existing models related to construction sector. This study is significant in two ways. Firstly, this review adds to the knowledge area of construction maturity model attributes by reviewing leading MMs and establish the foundation on developing a model template. Secondly, the industry practitioners would be able to use these attributes in developing more robust tools to evaluate the construction organisations and projects.

2. LITERATURE REVIEW

Construction maturity models have been in the constant development for few years. Initially, CMM which was developed by the Defence Department of the United states was used as a foundation to assess the maturity in the construction related organisation and projects (Nesensohn et al., 2014). With improvement the more updated version of CMM, the Capability Maturity Model Integrated (CMMI) becomes popular among many industries such as Information technology, Continuous improvement, Healthcare and Construction (Machado et al., 2021). However, since these models were not tailored to meet the dynamics in the construction sector, industry specialists began to develop more industry specific models (Marzouk et al., 2012). Providing a comprehensive report on organisation current status and capabilities, identifying maturity level of organisation, suggesting strategies to reach higher maturity (Facchini et al., 2020), providing incremental improvement guidelines (Lacerda & Wangenheim, 2018), comparing organisation with best practices to benchmark are key benefits of MMs (Machado et al., 2021).

Model attributes are the key factors that govern the assessing apparatus of the maturity models (Machado et al., 2021; Jayanetti et al., 2022). Apart from the term attributes, various models have used different terminology such as 'Enablers', 'key knowledge areas', 'capabilities' in terms of identifying these attributes. (Maneerat et al., 2015; Grossman, 2018; Khoshgoftar & Osman, 2009). Despite the fact of using different terms, they all elaborate the key assessing criteria of the models covering different scopes and disciplines in the construction project value adding chain from initiation to end. These attributes emphasis construction related aspects such as production efficiency, project management, supply chain integration etc. (Kwak & Ibbs, 2000; Willis & Rankin, 2012; Bendi et al., 2021). However, the literature suggests that even though these attributes are discussed in separate models individually, there is lack of evidence on critically reviewing model attributes holistically. Specially in several scenarios, the users of these models have argued that certain models ignore critically important aspects relating to construction sector, thus causing these models to be inadequate. Thus, this study attempts to identify the key attributes necessary for successful construction maturity assessment. In the process of reviewing construction MMs, the study identified 20 key construction related maturity models and presented in table 1.

Table 1: Maturity Models

Key Maturity Model	Source of Reference
Construction industry macro maturity model (CIM3)	Willis and Rankin (2012)
Project Management Maturity Model (PMMM)	Crawford (2006)
Capability Maturity Model Integrated (CMMI)	CMMI Product Team (2006)
Standardised Process Improvement for Construction Enterprises (SPICE)	Hutchinson and Finnemore (1999) Finnemore and Sarshar (2002)
Change Management Maturity Model (CM3)	Sun et al. (2009)
Organisational Project Management Maturity Model (OPM3)	Project Management Institute (PMI, 2003)
Maturity Assessment Grid (MAG) from the Strategic Forum for Construction	ICW Toolkit (2003).
Projects IN Controlled Environments (PRINCE2)	Williams (2010)
Off-site construction readiness maturity model (OCRMM)	Bendi et al. (2021)
OMG's business process maturity model (BPMM)	Gardiner et al. (2008)
Crosby's Quality Management Maturity Grid (QMMG)	Albliwi et al. (2014)
Construction supply chain maturity model (CSCMM)	Vaidyanathan and Howell (2007)
Berkley Project Management Process Maturity Model (BPMPMM)	Kwak and Ibbs (2000)
Portfolio, Programme and Project Management Maturity Model (P3M3)	Sowden et al. (2010)
Lean Construction Maturity Model (LCMM)	Nesensohn et al. (2014)
Project Management Process Maturity Model (PM)2	Kwak & Ibbs (2002)
Kerzner's project management maturity model (KPM3)	Kerzner (2005)
Program management maturity model for mega construction (PmM3)	Jia et al. (2011)
Prado-PMMM Model	Archibald and Prado (2014)
Integrated BIM-IPD-LC (BIL) maturity model	Rashidian et al. (2022)

These identified maturity models have evidently represented various attributes that the models have adopted to assess construction maturity. These identified models and respective attributes are comprehensively evaluated and presented in the analysis section of the paper.

3. METHODOLOGY

The study was initiated with the aim of studying and examining the existing construction model attributes. In addressing the aim, the authors adopted Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method to systematically identify key articles. As acknowledged by many scholars, PRISMA method is well known for extensively collate all the available data that would be ideal for a specific matter of study with a predetermined selection criterion (Sohrabi et al., 2021). Specially in an area like construction maturity models, where distinct studies provide varied results, it is imperative to analyse the key models to get a holistic understanding (Rethlefsen et al., 2021). Moreover, PRISMA technique allows the researcher to expand the search until the required data is gathered, providing a systematic guide on selecting the most suitable data to the study (Page et al., 2021). In this study, the authors used 'Web of Sciences, Google Scholar, Emerald and Science Direct', as key databases. A PRISMA systematic review requires a word search to examine through data bases selection criteria for the models. In the process, the authors searched '*Construction maturity models, Project management maturity models in construction, Construction maturity, Maturity, Maturity Models, Modern Maturity Models, Construction Maturity, Construction Management Maturity Models, AEC industry maturity models'* as key search words. Figure 1 presents the PRISMA document retrieval process.

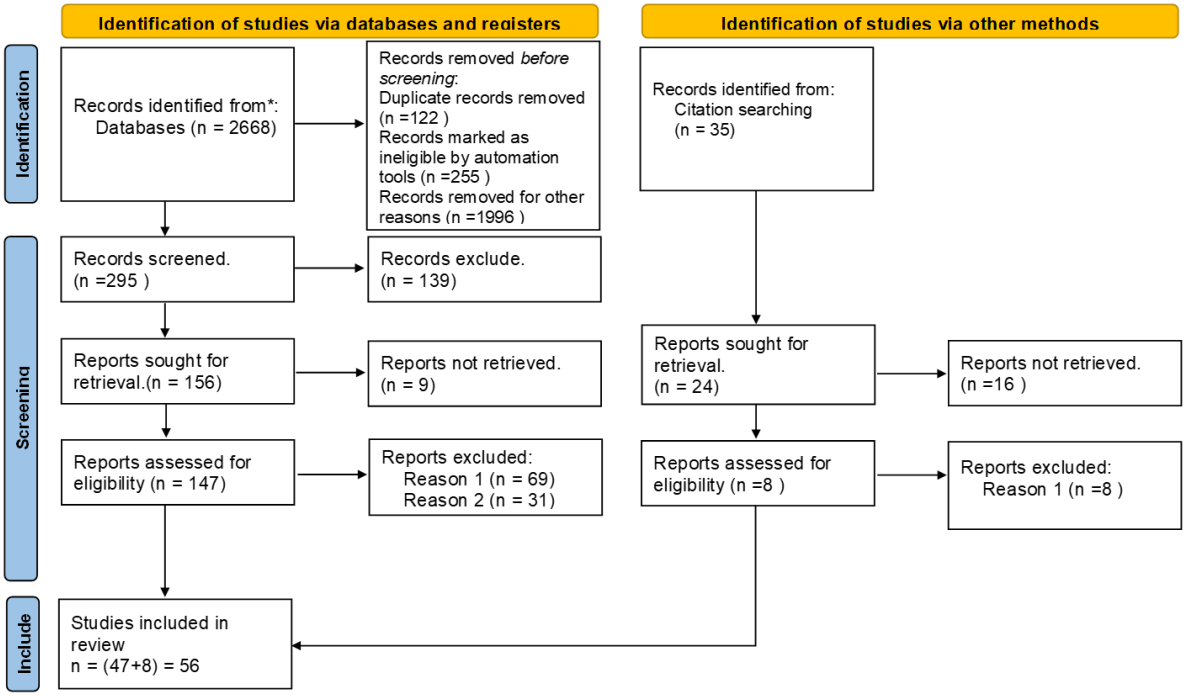

Figure 1: PRISMA process

Initially, a primary search was carried out using the above key words and from the results of that word search, 295 articles were selected for further screening. From those articles, through an abstract screening, 139 articles were excluded due to their incapability to the research scope and 156 articles were selected as suitable for further inspection. From the remaining, 156 articles were extensively studied and 47 articles were selected as suitable for the scope of the study. From those 47 articles, a reference search was carried out and another 8 articles were identified as appropriate for the study. Consequently, 56 total

number of articles were selected as the final set of articles used for the study. The criteria used for selecting the models are as follows:

1. The relevancy to the construction sector,
2. The relevancy to construction project management,
3. Existence and clear explanation of model attributes,
4. Explanation of use of attributes, and
5. Published by a reliable publisher.

These selected models are extensively studied and analysed using manual thematic analysis method. Thematic analysis (TA) is a technique for methodically locating, compiling, and providing understanding of patterns of meaning (themes) within a data collection. TA enables the researcher to see and make sense of common or shared meanings and experiences by concentrating on meaning across a data collection (Braun & Clarke, 2012). Thematic analysis is well suited for qualitative studies such as reviewing model attributes in the construction sector since they support to classify, compare, transliterate, and define qualitative data (Vaismoradi et al., 2016). Since reviewing the model attributes require forming themes systematically, the study adopted thematic analysis to analyse the data.

4. ANALYSIS AND FINDINGS

4.1 THE IDENTIFIED MATURITY MODELS AND ATTRIBUTES

The study identified 20 key construction related MMs through PRISMA method which presented distinct array of model attributes. These models were selected due to the prominence given to these models by the scholars as well as they exhibited model attributes elaborately to identify the exact meanings. These selected models represent various phases and products within the broad spectrum of construction. The model attributes are presented in table 2.

Table 2: Maturity model attributes

Key Maturity Model	Key Attributes	Source of Reference
CIM3	Procurement Management, Cost Management, Quality Management, Environment Management, Human Resource Management, Health, and Safety Management.	Willis and Rankin (2012)
PMMM	Integration Management, Time Management, Cost Management, Scope Management, Quality Management, Risk Management, Human Resources Management, Procurement Management, Communications Management	Crawford (2006).
CMMI	Agreement Management, Capacity and Availability Management, Causal Analysis and Resolution, Configuration Management, Decision Analysis and Resolution, Integrated Project Management, Measurement and Analysis, Organisational Process Definition, Organisational Process Focus, Organisational Performance Management / Organisational Innovation and Deployment Organisational Process Performance, Organisational Training, Product Integration, Project Monitoring and Control, Project Planning, Process and Product Quality Assurance, Quantitative Project Management, Requirements Development, Requirements Management, Risk Management, Supplier Agreement Management, Technical Solution, Validation	CMMI Product Team (2006)

Key Maturity Model	Key Attributes	Source of Reference
SPICE	Brief and Scope of Work Management, Project Planning, Project Tracking and Monitoring, Sub-contract Management, Project Change Management, Risk Management, Project Team Co-ordination, Commitment, Ability, Activity, Evaluation, Verification	Hutchinson and Finnemore (1999) Finnemore and Sarshar (2002)
CM3	Management Process, Risk Management, Communication, Management Information, Collaboration and Leadership/Objectives	Sun et al., (2009)
OPM3	Standardisation, Measurement, Control, Continuous Improvement, Project management, Program Management, Portfolio Management,	Project Management Institute (PMI, 2003)
MA	Supply Chain Integration, Project Team Integration, Culture	ICW Toolkit. (2003).
PRINCE2	Management Control, Benefits Management, Financial Management, Stakeholder Engagement, Risk Management, Organisational Governance, Resource Management	Williams (2010)
OCRMM	Operational challenges, Broad execution strategy, Planning certainty, Operational efficiency	Bendi et al., (2021)
BPMM	Planned innovations, Change management, Capable processes, Stable processes, Reuse/knowledge management., Predictable results, Productivity growth, Effective automation, Economy of scale, Repeatable practices, Reduced rework, Satisfied commitments, Productivity growth	Gardiner et al., (2008)
QMMG	Management understanding and attitude, Problem handling, Quality improvement actions, Quality organisation status, Cost of quality as % of sales, Summary of company quality posture	Albliwi et al., (2014)
CSCMM	Process Assessment, Technology Assessment, Strategy Assessment, Value Assessment, Functional integration, Multi-project integration, Multi-firm integration	Vaidyanathan and Howell (2007)
BPMPMM	Integration, Scope, Time, Cost, Quality, Human Resource, Communications, Risk, Procurement	Kwak and Ibbs (2000)
P3M3	Management Control, Benefits Management, Financial Management, Stakeholder Engagement, Risk Management, Organisational Governance, Resource Management, Portfolio Management, Programme Management, Project Management	Sowden et al., (2010)
LCMM	Leadership, Customer focus, Way of thinking, Culture & behaviour, Competencies, Improvement Enablers, Processes & tools, Change, Work environment, Business results, Learning, Competency development	Nesensohn et al., (2014)
(PM)2	Integration Management, Time Management, Cost Management, Scope Management, Quality Management, Risk Management, Human Resources Management, Procurement Management, Communications Management	Kwak and Ibbs, (2002)
KPM3	Common Language, Common Process, Singular Methodology, Benchmarking, Continuous Improvement	Kerzner (2005)
PmM3	Integration Management, Time Management, Cost Management, Scope Management, Quality Management, Risk Management, Human Resources Management, Procurement Management, Communications Management	Jia et al., (2011)
Prado PMMM Model	Competence in Project and Program Management, Competence in Technical and Contextual Aspects, Behavioural Competence, Methodology usage, Computerisation, Usage of the convenient Organisational Structure, Strategic Alignment	Archibald & Prado (2014)

Key Maturity Model	Key Attributes	Source of Reference
BIL	Leadership, Customer Focus, Way of Thinking, Culture & Behaviour, Improvement Enablers, Competencies Processes & Tools, Work Environment, Business Results Learning & Competency Development	Rashidian et al., (2022)

4.2 THEME DEVELOPMENT FOR MODEL ATTRIBUTES

Analysing the models, the authors were able to identify patterns and close relationships among many model components even though the models used different terminologies. For instances, CMMI uses the term *Process Performance*, whereas BPMM offer the term *Operational Efficiency* to describe the same characteristic within the construction projects (CMMI Product Team, 2006); Bendi et al., 2021). Thus, by the use of thematic analysis, following key themes were identified among models. Table 3 represents how the themes were developed dissecting the model attributes.

Table 3: Identification of key themes in model attributes

Key Attribute (Key Theme)	Contributions from the models
Operational Efficiency	Brief and Scope of Work Management, Project management, Program Management, Portfolio Management, Measurement and Control, Management Control, Process & tools Assessment, Project Time Management, Project Planning, Project Tracking and Monitoring, Operational challenges, Capacity and Availability Management, Value Assessment, Capable processes, Stable processes, Common Process, Repeatable practices, Reduced rework, Productivity growth
Strategic Human Resource Management	Organisational Training, Collaboration and Leadership, Project team integration, Business results, Leadership, Competencies, Improvement Enablers, Requirements Development, Organisational Governance, Resource Management, Broad execution strategy, Strategy Assessment
Knowledge Management	Continuous Improvement, Planned innovations, Effective automation. Multi-project integration, Economy of scale, Technology Assessment Reuse/knowledge management, Learning, Competency development
Project Quality Management	Quality Management, Process and Product Quality Assurance, Project Monitoring and Control, Measurement and Analysis, Predictable results Benchmarking, Singular Methodology
Consideration for customer value	Benefits Management, Stakeholder Engagement, Satisfied commitments. Customer focus, Value Assessment
Supply Chain Integration	Sub-contract Management, supply chain integration, Functional integration, Multi-project integration, Multi-firm integration, Portfolio Management, Integrated Project Management
Communication	Common Language, Organisational Process Definition, Management Information
Change Management	Risk Management, Way of thinking, Culture & behaviour
Procurement Management	Procurement Management, Agreement Management, Sub-contract Management
Standardisation	Standardisation, Benchmarking, Singular Methodology
Cost Management	Cost Management, Financial Management
Environment Management	Environment Management
Health and safety Management	Health and Safety Management

As depicted in table 3, 13 key attributes were identified within the studied construction maturity models. As evidenced, prominence was given to production/construction component of the value chain. Thus, operational efficiency was identified as a key theme covering broad aspects like construction management, process management, project management, work scope management, identifying operational challenges, process measurement etc. Strategic human resource management (SHRM) and Knowledge Management are also identified as key themes. Among the model attributes, SHRM is a key theme covered many areas related to construction maturity such as developing capabilities and competencies, leadership, and drive of organisation to its aim and goals, identifying the skills requirement and creating project teams. Knowledge Management is also a much-noted theme among model attributes in areas such as continuous improvement, technological advancements, innovations, knowledge sharing etc. Quality Management is a key theme highly visible throughout the model attributes due to its importance in construction sector. Key aspects like quality control, project monitoring and control and quality assurance are referred under this theme.

Customer satisfaction is also a key theme among model attributes. Stakeholder engagement, satisfied commitments, delivering customers need were seemed to be key considerations among model attributes. Supply chain integration is also another key factor that has taken the emphasis among model attributes. As many scholars have also expressed, upward and downward supply chain integration is widely accepted among the key model attributes. Successful communication throughout organisation is also identified as a key theme which resonated among model attributes. Clear communication channels, Defined processes were few of the key factors considered in this regard. Change Management, Procurement Management Standardisation and Cost Management were also identified as common attributes among the studied models. Lastly, even though not commonly visible as other themes, Environmental Management and Health and Safety Management were also identified themes amongst the evaluated model attributes.

4.3 DISCUSSION

As per the analysis, all the models have emphasised the importance of operational efficiency as a key indicator of construction maturity models. This notion is well supported by many industry practitioners and scholars as they emphasised the importance in efficient operation to minimise the deficiencies in the construction sector (National Research Council, 2009; Anees et al., 2013; Choudhry, 2017). Many models have identified that SHRM to be a key success factor for reaching higher construction maturity. On a similar note, numerous studies have proven that building a competent work force, enabling the employees, and leading them to strategic goals of the organisation is particularly important in reaching higher levels in construction industry (Kaewnaknaew, 2022; Druker et al., 1996). This argument is justified in many models since many models such as PM2, CMMI, SPICE, CM3, PRINCE 2, BPMM, CSCMM, CIM3, BPMPMM, P3M3 have all adopted Human Resource Management as a key attribute in structuring the models (Finnemore & Sarshar, 2002; Fryer et al., 2013; Gardiner et al., 2008; Pane & Sarno, 2015; Sun et al., 2009; Vaidyanathan & Howell, 2007; Willis & Rankin, 2012).

Numerous models have identified the importance of Knowledge Management as a key driver for success in the gradually improving construction industry. This is further confirmed by the evidence in literature (Regona et al., 2022). Models such as OPM3 have discussed about using project integration techniques in order to enhance the efficiency and

the swiftness of works (Machado et al., 2021). Several models such as PM2, CMMI, SPICE, OPM3, BPMM have mentioned this attribute to be essential to assess construction maturity (Finnemore & Sarshar, 2002; Khoshgoftar & Osman, 2009; Pane & Sarno, 2015). Project Quality Management is an attribute, which was overwhelmingly accepted by many models. This idea is well supported by the scholars as they outline maintaining quality is a key essential in construction project success (Hoonakker et al., 2010; Ashokkumar, 2014). Evident by the collected data PM2, MAG, PRINCE 2, OCRMM, CSCMM, CIM3, BPMPMM, P3M3 have highly emphasised the ways and means of Quality Management enhancing the overall maturity of firms.

Customer centric approach clearly remains a common attribute among majority of the models. As proven by the literature, in any business, the importance of customer satisfaction is paramount for success (Stoppel & Roth, 2017). Thus, the models have mentioned various process areas which can be placed under the theme, customer centric approach. Models such as CMMI, CIM3, OCRMM have identified client focus to be one of major attributes (Bendi et al., 2021; Gudergan et al., 2015).

Supply chain integration and clear communication among all the channels through the value chain is also identified to be a key assessment criterion in construction maturity. Many scholars and industry specialists have proven that better supply chain integration is paramount (Sari et al., 2023). Proving the notion, many models have clearly outlined the importance of supply chain integration in measuring construction maturity. CMM, CMMI, MAG, CIM3, BPMPMM have mentioned that clear links and in-house supply chain integration as key criteria in maturity assessment (Kwak & Ibbs, 2000; Pane & Sarno, 2015; Willis & Rankin, 2012). Clear communication is identified as a key theme for measuring maturity. In construction environment, a considerable amount of data is shared and it needs to be communicated among all the relevant stakeholders to maintain speed and accuracy (Wikforss & Löfgren, 2007). PM2, CM3, OPM3, MAG, QMMG, BPMPMM, P3M3 have adopted communication as a core attribute (Machado et al., 2021; Sun et al., 2009).

Change Management is a key attribute that has resonated among several models as an important factor relevant to reach higher maturity. This attribute goes in line with aspects such as Risk Management and creating a culture inducive to new methods. Many scholars have proven that creating an environment where new ideas and change is welcomed, creates a better atmosphere for improvement (Dainty et al., 2007; Ankrah, 2007). Procurement Management has always been a key driver of success in the field of construction (Araújo et al., 2017). However, out of the 20 MMs studies, only six MMs have explicitly expressed this attribute. This suggests that even though procurement is a key part of the value chain of construction, majority of the models have failed to integrate it in the model assessing criteria as a key attribute.

A key barrier for success in construction industry is the lack of standardisation (Ahmed et al., 2021). A model which has been used as a benchmark to develop other construction maturity models is CMMI. The CMMI clearly cited that standardised work practices is a key assessing factor in their maturity assessment (Software Engineering Institute, 2006). Following the same principle, many models such as, SPICE, MAG, OCRMM, BPMM, CSCMM, BPMPMM have identified the importance of standardisation in construction and considered it to be a core criterion to assess construction maturity.

Cost Management is undisputedly a key measure for evaluating the success of construction related projects (Potts & Ankrah, 2008). Contemplating with that notion, majority of the

examined models have expressed the inclination to include a factor covering this attribute. Finally, Environmental Management and Health and Safety Management are the least favoured attributes among the models. Predictably, the literature provides a clear explanation that supports this phenomenon. Many studies have concluded that even though environmental and Health and safety management are important aspects in the construction sector, firms tend to offer less significance to these factors as they do not directly elevate the financial prowess (Morel et al., 2001; Muhammad et al., 2015). Thus, models have not extensively considered these two attributes.

4.4 THE WAY FORWARD

Identifying attributes of construction related maturity models is the first step of a larger research on developing a conceptual maturity model template for construction sector. The literature suggests that apart from key attributes, there are several other key components that are imperative in assessing construction maturity as shown in figure 2.

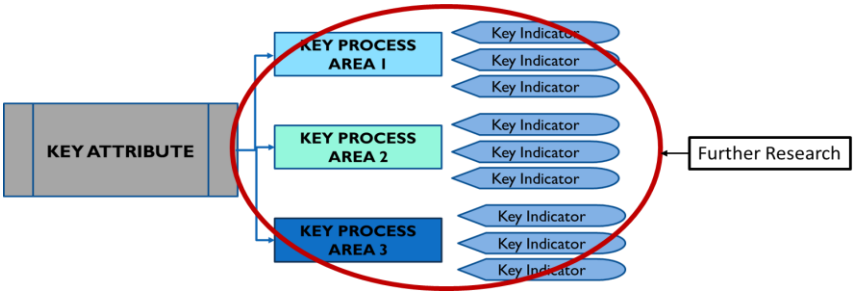

Figure 2: Key model components

Therefore, further research must be carried out to identify how these key attributes can be understood under various key process areas that would elaborate a key attribute in numerous aspects. The next step of the study would be to identify key indicators that would enable to assess these criteria practically in the construction process. Ultimately, identifying all these key model components and themes would provide a foundation to develop a conceptual model template.

5. CONCLUSIONS

Even though several construction MMs exist, a gap was identified on a comprehensive review on model attributes. Therefore, this research was initiated with the aim to review the existing construction MM attributes and to identify their themes and patterns. PRISMA systematic review method identified 20 key construction maturity models and their respective attributes, and they were analysed using thematic analysis. Through the analysis, 13 key themes were identified. These themes were then examined corresponding to the MMs and their relationship comprehensively. Findings of this study contribute to both the knowledge base and industry. This paper integrates all the key attributes relating to prominent construction related MMs and explain the current state of knowledge. The study identified key themes among model attributes and opens new avenues to develop a resilient MM template covering all the relevant aspects of construction. From an industry perspective, practitioners have the ability to use the findings to organise their work practices and develop more pragmatic models to solve impending issues in the construction industry. Further this study encourages the use of MMs and attributes in the field of construction to attain better results and to reach higher maturity. This research is limited in terms of construction maturity model attributes. Therefore, scholars are encouraged to

study in more depth to identify functional aspects and key indicators of these attributes and their behaviour.

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