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Building Information Modelling for Project Managers





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Report for Royal Institution of Chartered Surveyors

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Contents

Foreword	6
Executive Summary	8
1.0 Introduction and Background	9
1.1 Purpose of the Insight Paper	9
1.2 Brief Overview of BIM	9
1.3 Why is BIM Important for the Built Environment?	10
1.4 Why is BIM Important for Project Managers?	10
1.4.1 Defining Projects and Project Management	11
1.5 BIM Adoption by Stakeholders	11
1.6 BIM Adoption and Maturity Level	12
1.7 Structure	12
2.0 Use of BIM in Project Delivery – Role of the Project Manager	13
2.1 Project Managers and the BIM-based Project Ecosystem	17
2.1.1 The Employer's BIM Requirements	19
2.1.2 BIM Execution Plan [BEP]	20
2.1.3 Master Information Delivery Plan [MIDP]	20
2.2 BIM, Project Management Functions, and the Project Lifecycle	21
2.2.1 BIM during the Brief, Concept and Definition Stages	22
2.2.2 BIM during the Design Stage	23
2.2.3 BIM during Construction and Commissioning Stages	23
2.3 Communication, Coordination, and Collaboration	25
2.3.1 Common Data Environment [CDE]	26
2.3.2 BIM Collaboration Framework [BCF]	26
2.4 Implications of BIM for Project Managers	27
2.5 Defining Metrics for Successful BIM Implementation	28
2.6 Changes in Contractual Arrangements	28
2.7 Assessing BIM Maturity At the Project Level	29
3.0 Strategic Issues Pertaining to BIM and Project Management	30
3.1 BIM Adoption Decision	30
3.2 Developing a BIM Vision	31
3.3 Organisational Leadership and BIM Leadership	31
3.4 Organisational Implementation Framework	31
3.5 Developing Organisational Capabilities	32
4.0 Future of BIM and Project Management	33
4.1 Broader Role of Project Managers	33
4.2 Emerging Technologies and Paradigms	34
5.0 Conclusions and Recommendations	36
6.0 References	37
7.0 Bibliography	39

Figures

Figure 1	Relationship of BIM to the Project Manager's Roles and Responsibilities.....	13
Figure 2	BIM-related Effort expended over the Project Lifecycle	15
Figure 3	Project Management and BIM Management.....	16
Figure 4	The Project Ecosystem and BIM.....	18
Figure 5	BIM Management Framework	18
Figure 6	Master Information Delivery Plan	20
Figure 7	Development of the Building Information Model	21
Figure 8	BIM during Briefing, Concept and Definition Phases	22
Figure 9	Design, Construction, and Coordination	25
Figure 10	BCF based clash prevention and resolution process.....	27
Figure 11	Organisation Level BIM Implementation Framework.....	32
Figure 12	Broader Role of Project Managers in BIM Implementation	34
Figure 13	Emerging Technologies and Paradigms in the Built Environment Sector.....	35

Tables

Table 1	BIM-Based Classification of Project-Specific Roles and Responsibilities.....	14
Table 2	Main Contents of BEP	20
Table 3	Overview of a project manager's BIM role over the project lifecycle.....	21
Table 4	Some Features of the CDE platform.....	26
Table 5	Influence of BIM on Project Management Knowledge Areas.....	27
Table 6	BIM Based Classification of Strategic and Advisory Roles and Responsibilities.....	30
Table 7	Organisation Level BIM Implementation Framework.....	32

Foreword

BIM continues to dominate processes across the built environment. It offers extensive opportunities to drive a more effective and efficient built environment. However, much of the information and debate surrounding BIM is centred on design aspects, while Chartered Surveyors tend to be more involved in the business management of projects. From initial concept through to asset and facilities management, the surveyor's role focuses on commercial cost management.

RICS has already produced guidance for quantity surveyors and building surveyors on BIM. But it is probably even more critical that project managers are clear on the potential and capability of BIM to transform construction projects. In the government and private sector, project clients are starting to mandate the effective use of BIM on their projects. Setting this agenda forces a collaborative framework and enables the benefits to be driven through design, construction and operations teams.

The construction industry has suffered from low productivity for some time. The industry is one of the largest in the world economy, but its productivity has fallen behind that of other sectors for decades. A McKinsey report, published in February 2017, noted that the global construction sector's labour-productivity growth averaged just 1 percent a year over the past two decades. This is compared with 2.8 percent for the total world economy, and 3.6 percent for manufacturing. The report concludes that a key way to improve the poor productivity in our industry is by using digital technology. Of course, you also need the right management capability to utilise it fully. BIM is central to project managers obtaining the right information, from the right person, in the right form, and at the right time.

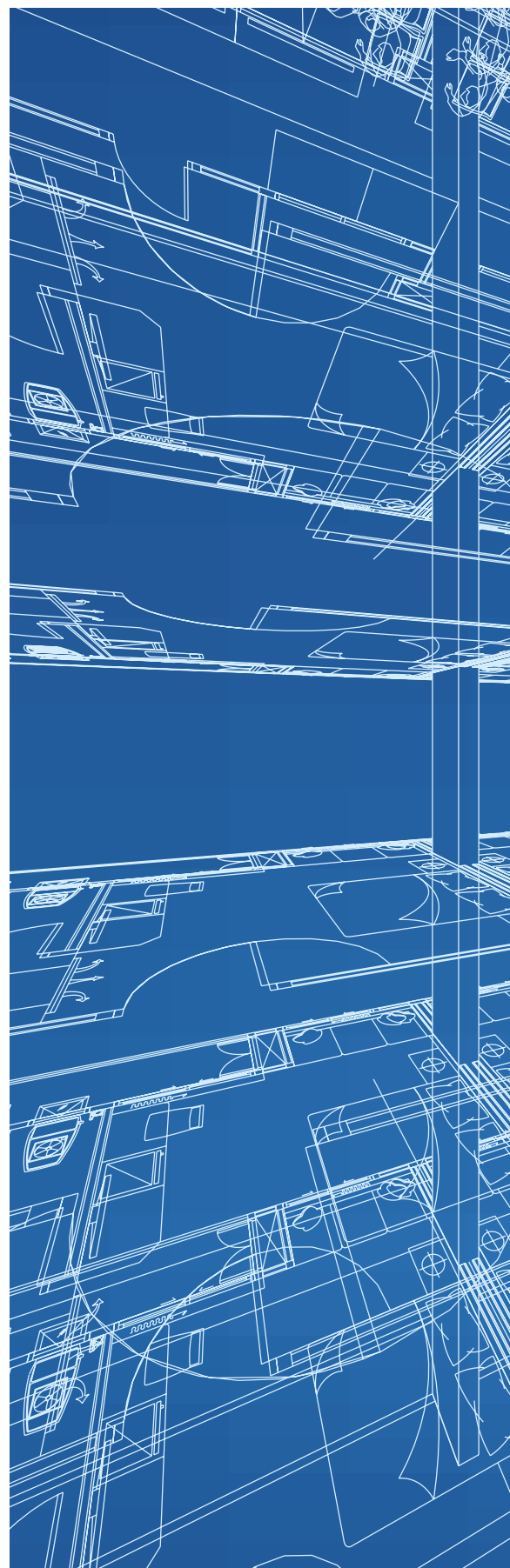
It is essential that, as a global profession, we take a global perspective. This Insights paper has been written with the world view of project management in construction in mind. It is relevant to project managers working in client, consultant and constructor organisations, and across all markets.

It spans this spectrum by covering organisational strategic issues, and the role and functions of project managers in BIM implementation. It also looks to the future, at how roles might evolve as BIM continues to develop.

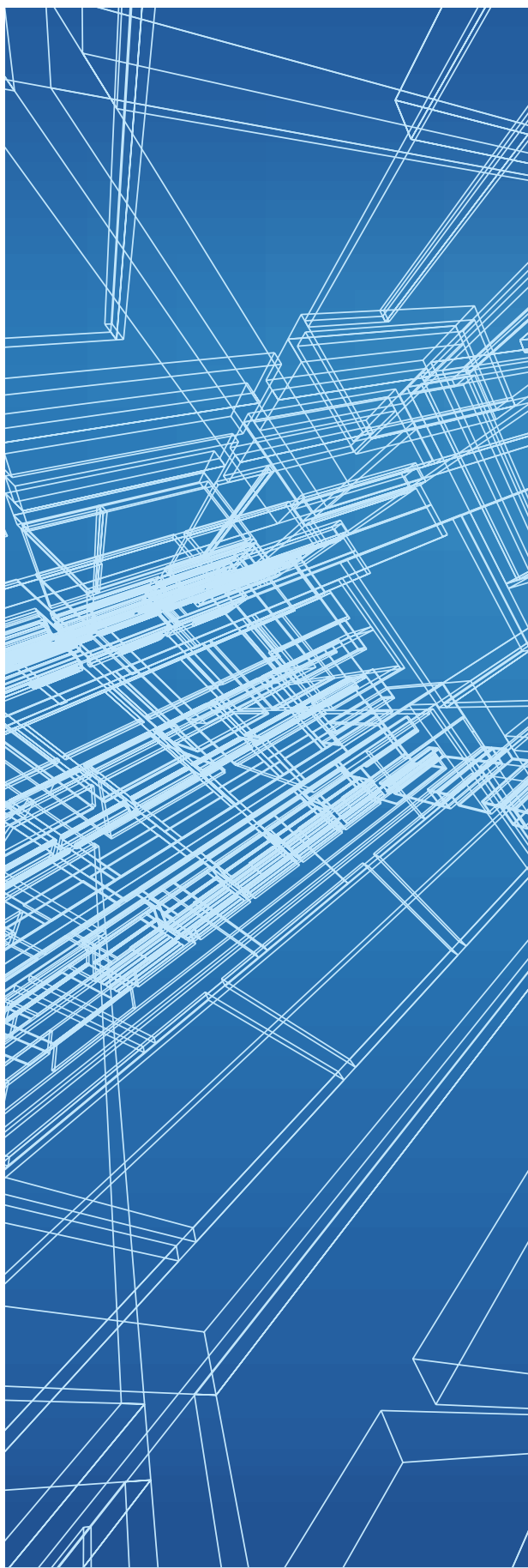
BIM provides us with the opportunity to drive efficiency in our project management processes, and I hope this paper inspires you about how we can achieve this. By seeing the future today, through the effective use of BIM, we can improve the planning and delivery of projects to achieve better outcomes for our clients and the public at large.

Amanda Clack FRICS

RICS President 2016/17







Executive Summary

Project managers in the built environment are beginning to take notice of the industry developments pertaining to Building Information Modelling (BIM). With more projects and organizations beginning to use BIM in meaningful ways, the role and responsibilities of a project manager are changing. As the integrators of people, processes, and organisations, project managers can utilize BIM to deliver their project-level and organization-level services in a far more effective fashion. As both BIM and project management centre around the themes of “collaboration”, “coordination”, “communication”, “exchange”, and “collation”, there is a significant overlap between the two. This paper explores this overlap by describing the impact of BIM on a project manager’s roles, responsibilities and functions.

Both project-specific and strategic or advisory roles and responsibilities at the organization level are discussed.

The paper utilizes the international project management standards available to outline the roles and responsibilities of project managers in a standardized way and to determine the impact of BIM on these roles and responsibilities. By classifying these roles and responsibilities into “driven by BIM”, “driving BIM” and “driven by BIM and driving BIM” groups, this paper offers an augmented understanding of the impact of BIM on project management. The paper also highlights the use of BIM by a project manager over the entire lifecycle of a project. The strategic and advisory functions of a project manager in helping an organization undertake BIM transformation are also covered.

BIM can be used by project managers to improve communication, coordination, and collaboration on projects. In their roles as “integrators”, they can ultimately drive the use of a Common Data Environment and BIM Collaboration Format to increase operational efficiencies of project teams. Ultimately project managers can use BIM as a catalyst to improve collaboration, enhance shared ownership of project goals, and drive synergies between the project plan, design strategy and BIM strategy, thereby increasing the level of engagement in project teams.

Project managers can help organizations adopt BIM in a more holistic fashion and provide strategic advice on the overall transformation of the organization. For this to happen, project managers must take a more central role in the BIM discourse and amend their roles, responsibilities, and practices in line with industry-wide changes. It is critical to examine the project management body of knowledge and competencies in conjunction with the usage of BIM by the industry. They must also evaluate at a strategic level the long-term impacts of emerging trends and paradigms that are directly and indirectly linked to BIM.

1.0 Introduction and Background

Building Information Modelling (BIM) is improving the way projects are delivered and completed assets are managed around the globe. It provides a revolutionary platform for “rethinking” how we design, construct, maintain, and operate our built environment. Additionally, BIM is also changing the way we are enacting improvements (rehabilitation, retrofit, and redevelopment) to existing assets in the built environment.

We have now reached an exciting stage in BIM’s evolution where a significant number of the stakeholders in the built environment sector are either using BIM or are considering its use. For example, as outlined by the Intergovernmental Panel on Climate Change, 86% of the respondents in the UK expect to be using BIM on at least some of their projects by 2017 (Intergovernmental Panel on Climate Change, 2016). This evolution is particularly relevant in mature markets, though the level of adoption of BIM varies by country, by the size and complexity of the projects, and also by the size and nature of each specific organisation.

Among some of the least talked about stakeholders in this context are the project managers. This paper aims to address this balance by outlining the pertinence of BIM to project management as a discipline and, inversely, the importance of BIM-integrated project management to effective project delivery in the built environment.

It describes BIM from the worldview of a project manager by defining the project management processes operating in a BIM-enabled environment, and by highlighting future trends in project management practice that could result from the adoption of emerging technologies in the built environment sector.

Since project management as a discipline is practised by various members of the project team, this paper addresses issues important to project managers who may be part of the owner’s organisation, constructor’s organisation or the project management consultant’s organisation.

1.1 Purpose of the Insight Paper

By providing forward-looking, high-level principles from the project manager’s perspective, this paper addresses the following issues about the use of BIM in the built environment:

1. Role and function of the project manager in BIM implementation across different types of projects, including BIM-driven changes to existing project management roles, responsibilities and practices;
2. Strategic issues about the use of BIM at the organisational (owner’s organisation, constructor’s organisation or the project management consultant’s organisation) level including adoption advice; short-term and medium-term planning for implementation; organisational learning and knowledge management; and other similar strategic issues;
3. Articulation of a roadmap for future directions for project managers as BIM adoption and maturity levels progress, including discussion of the impact of other BIM-related emerging technologies and trends in the sector; development of new or revised project management competencies; and the resulting need for further learning and development.

1.2 Brief Overview of BIM

BIM, as a paradigm, changes the ways in which industry players in the built environment sector work, shifting away from inefficient processes and practices driven by static (two-dimensional) drawings and documentation towards model-centric processes and practices. BIM is seen by many as an integrated information system that helps in effectively assimilating the organisational functions and processes of project delivery. BIM can be defined in diverse ways, resulting in the many definitions that are in use today. The following definition provided by the UK Building Information Modelling Task Group perhaps provides the most robust articulation behind the technology, people and process dimensions of BIM:

‘BIM is essentially value creating collaboration through the entire life-cycle of an asset, underpinned by the creation, collation and exchange of shared 3D models and intelligent, structured data attached to them.’¹

¹ <http://www.bimtaskgroup.org/bim-faqs/>

The effects of BIM cannot be looked at the technology level alone, as it also has far-reaching implications for people, organisations, processes, and practices in the built environment. Many experts feel that BIM is a game-changer (Eastman et al., 2011a), that, when coupled with other industry trends, is bringing about change in the sector's value chain in the following ways:

- Reshaping (by making them more effective) the roles and responsibilities of people, projects, and firms throughout the built environment;
- Impacting the entire life cycle of the project and world view of major stakeholders;
- Improving the underlying 'operating system' of the built environment sector; and
- Impacting the way in which a project is delivered, by affecting all the project processes.

For additional information on BIM, the reader may reference the documents listed in the Bibliography section of this report.

1.3 Why is BIM Important for the Built Environment?

BIM is considered by many to be a remarkable development that has encouraged the built environment sector across the globe to rethink how we undertake our core project-centric processes (Eastman et al., 2011a; Succar, Sher and Williams, 2012; Sawhney, 2014).

Fundamentally a technology-enabled way of working, BIM, when combined with the dimensions of people, processes, and organisations, has the potential to impact the industry significantly. As a mechanism, it facilitates the creation, storage and sharing of project information by a project team in a way that is far superior to the current (static and predominantly paper-based) methods of information generation, sharing and use. Theoretically, it could be said that BIM can help achieve many of the lofty goals the industry has set for itself (Kreider and Messner, 2013). However, one debate that has raged within the industry relates to how BIM is pitched to the constituents of the sector—some going as far as saying that BIM is being oversold in its potential to solve industry challenges.

So is BIM the panacea that the industry has been looking for?

This is certainly not the case. All the shifts, changes and improvements propagated by the proponents of BIM rest on the ability of a project team to produce and use high-fidelity models that are information rich. While BIM by its very nature is less prone to mistakes, any inefficiencies that creep into the models will obviously lead to lower than expected benefits.

While the industry has made significant progress in the application of BIM during the design phase of projects, there is a consensus that downstream uses of BIM have not matured at the same pace. Project managers have the potential to change this by filling in the biggest 'gap' in the BIM conversation that occurs early on in the project lifecycle—during the briefing of clients on the benefits (and challenges) of adopting BIM. Client briefing is a crucial opportunity for adding value and should be the natural terrain for project managers to establish their role at this initial stage to guide the BIM process after that.

One thing is becoming clear; if deployed correctly, BIM could allow the built environment sector to attain the same kinds of productivity gains that have been seen in the aerospace, automotive, and manufacturing industries.

1.4 Why is BIM Important for Project Managers?

To some extent, project managers have been left out of the mainstream action on BIM—partly due to lack of engagement on their part and partly because the front-end use of BIM in design has been in the limelight. This situation needs to change—effective project management is critical to ensuring successful BIM implementation and successful project delivery.

Why is the role of project managers on BIM projects so important?

The answer lies in the very definition of BIM. From the definition, one can discern key themes of "collaboration," "coordination," "communication," "exchange" and "collation" that are relevant to answering questions about the impact of effective project management in BIM implementation. As per the RICS APC Pathway Guide on Project Management, "*Project managers occupy a central role in the development process driving successful completion of projects.*" (RICS, 2015a)

It is well established that effective project management contributes to project success (Carvalho, Patah and de Souza Bido, 2015; Joslin and Müller, 2015). This requires the roles and responsibilities of the project manager to be clearly defined. In today's context, when the use of BIM is likely to become mainstream, this aspect still holds true—rather than diminishing the role of the project manager, BIM actually enhances and sharpens it.

Fundamentally, the key role every project manager plays on projects is that of bringing together a disparate group of experts and integrating their knowledge into a buildable design that meets cost, quality, safety, sustainability, and schedule objectives and requirements, and generates value for the project sponsor, project team members, and end-users. The project manager plays a key role as the “Project Integrator”, being responsible for the integration across the temporal dimension of the project (the various project lifecycle stages) as well as across the dimensions of organisations, processes, and information. The ultimate success of a project depends on how effective the project manager can be as an integrator across these dimensions. With BIM as a fundamental enabler for effective integration, it is crucial for project managers to understand how to harness and use it for their projects.

1.4.1 Defining Projects and Project Management

In order to understand this role, it is important to first define projects and project management in ways that are globally accepted by the industry and fit well into the discourse on BIM.

The guidance note entitled “Appointing a project manager” (RICS, 2013) defines a project as *“An undertaking to achieve a specified objective, usually defined in terms of technical performance (scope), cost (budget) and time (programme or schedule). Projects are characterised as being unique and having a defined start and end.”* There are similar definitions of projects provided by other standards organisations such as the Project Management Institute, Association for Project Management, and International Project Management Association.

Similarly, many definitions of **project management** are also available and in use globally. Project management is defined in the BS ISO 21500 as *“The application of methods, tools, techniques and competencies to a project. Project management includes the integration of the various phases of the project lifecycle.”* (British Standards Institute, 2012). BS 6079-1:2010 further defines project management as *“the planning, monitoring and control of all aspects of a project and the motivation of all those involved in it to achieve the project objectives on time and to the specified cost, quality, and performance.”* (British Standards Institute, 2010)

Within the context of projects and project management, the term **project manager** is then used to refer to *“(t)he person, practice or employee appointed by an employer to lead and manage the project and be accountable to the project sponsor or project board for its successful completion.”* (RICS, 2013).

The BS 6079-1:2010 defines a project manager as *“a person accountable for the day-to-day management of a project, with a focus on delivering outputs, which will enable the required outcomes and benefits to be realized.”* (British Standards Institute, 2010)

Project managers can be universally deployed on all types of projects including building and (non-building) infrastructure projects. Their roles and responsibilities occur at many levels of the project delivery network and the supply chain. The project manager leads and directs the project participants while managing the project and is accountable to the project sponsor for the successful completion of the project (RICS, 2013).

This paper takes the above definitions and discusses these in the context of the projects and organisations that use BIM to support project delivery, explaining in high-level terms what BIM can do for the project manager and what the project manager has to do for BIM implementation on projects. Ensuring that project managers embrace BIM and in fact play a crucial role in BIM implementation on projects will be important in ultimately driving BIM adoption and its efficient and successful usage. Additionally, this paper also highlights the strategic role a project manager plays in advising organisations that are using or considering using BIM. In this way, this paper covers both project-level and organization-level issues.

1.5 BIM Adoption by Stakeholders

Architectural firms have been among the first to adopt BIM (McGraw Hill Construction, 2014; National Building Specifications, 2015) — design team initiation is the most common method for BIM adoption, reported at 58% in the US and 90% in the UK (McGraw-Hill Construction, 2014). A study by Elmualim and Gilder found that the encouragement of the design team, in addition to that of the client, increases the chances of successful BIM adoption and implementation (Elmualim and Gilder, 2014). Anecdotal there are reports that some speciality contractors were early adopters of BIM.

In most mature markets, BIM adoption has become much more pervasive with some countries reporting BIM adoption among contractors exceeding that by architects and designers. In countries where BIM usage is high, it has also become evident that the initial “lonely” BIM transition has either yielded or is yielding to a more collaborative or social form of BIM.

Two major stakeholders who are perceived to be behind the curve in BIM awareness and adoption are quantity surveyors and project managers.

Lately, much has been written regarding the adoption of BIM for measurements, quantity-take-off and cost planning, with the professional guidance note 'BIM for cost managers: requirements from the BIM model' (RICS, 2015b) as a notable example.

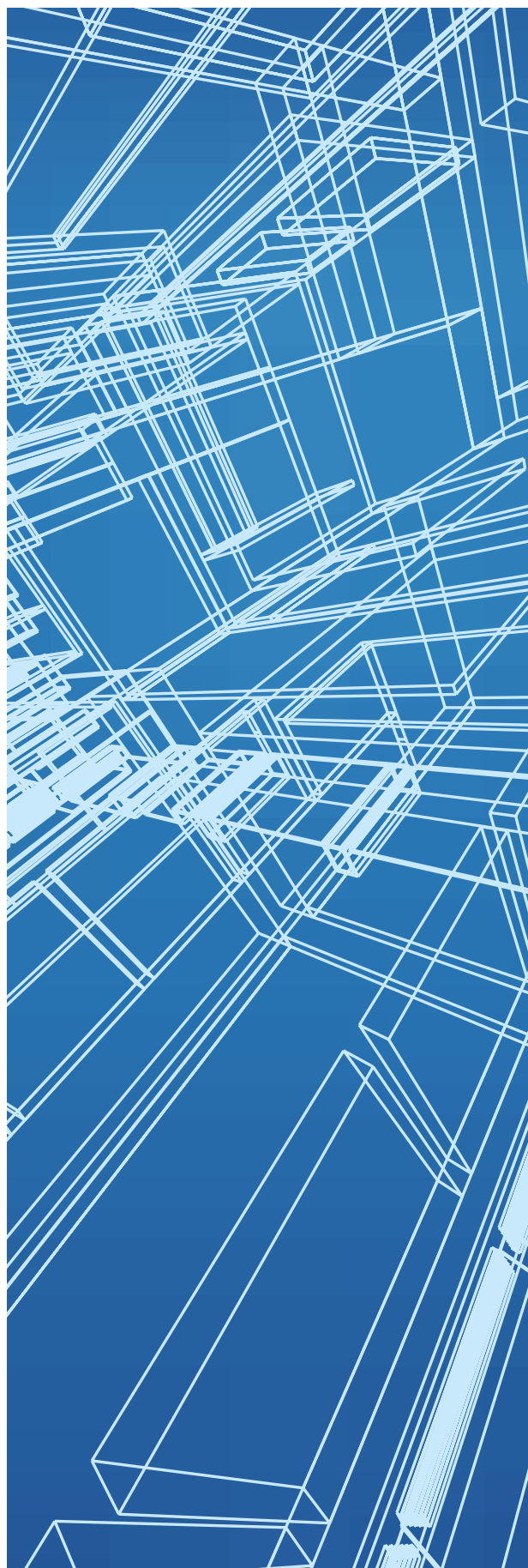
However, there is a gap in knowledge when it comes to BIM for project management. This paper strives to fill this gap.

1.6 BIM Adoption and Maturity Level

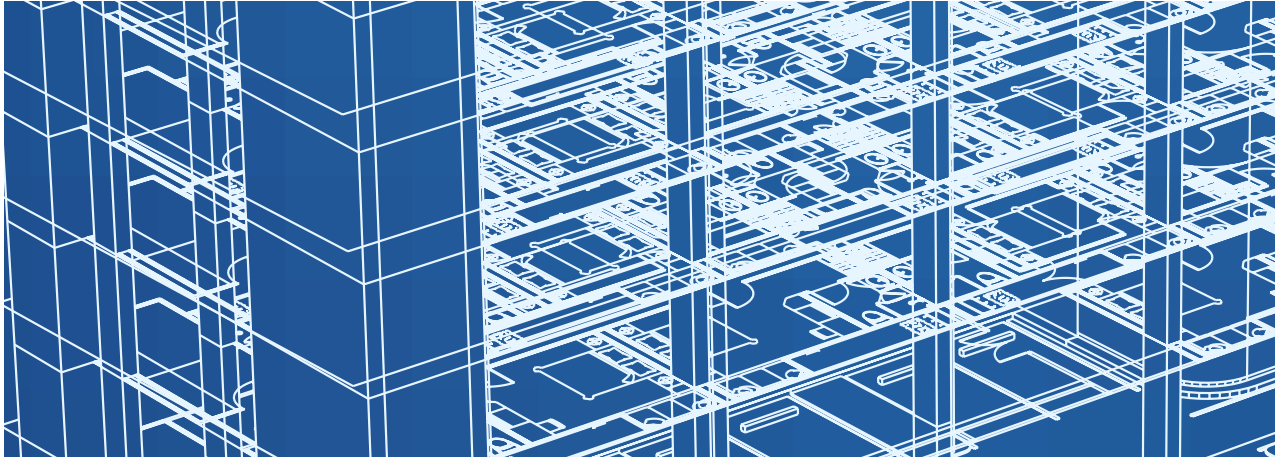
Before we begin discussing the roles and responsibilities of the project manager, it is vital to understand the status of BIM adoption and its level of maturity in the context of the project, the organisation and the marketplace. Leaving aside the problematic stories of 'BIM wash', it is important to outline clearly what is meant by the implementation of BIM on a project in a given location by the chosen project team. The de facto industry doctrine on this topic is the concept of "BIM Levels" as propagated in the BIM Strategy Report published by the UK Government in May 2011 and described in the BS 1192-4:2014 standard (British Standards Institute, 2014). The level of BIM maturity is the "ability of the construction supply chain to operate and exchange information". The maturity model has four levels (level 0 to level 3) that are designed to allow the (government) client to understand what is being offered by the "supply chain on a project that uses BIM". Readers interested in understanding the maturity model in more detail can read the "BIM Strategy Report" produced by the BIM Industry Working Group on behalf of the UK Department of Business, Innovation and Skills (Department of Business Innovation and Skills, 2011).

1.7 Structure

This paper focuses on BIM from the point-of-view of a project manager and takes an agnostic approach to the type, size, and nature of the project. Section 1 provides a brief introduction and background to BIM within the context of project management. In Section 2 the role of project management in BIM-based project delivery is described. This section also highlights the role of a project manager on projects that use BIM. The strategic advisory role of project managers at the organisation level is described in Section 3. Section 4 provides a summary discussion of the future of BIM and project management.



2.0 Use of BIM in Project Delivery – Role of the Project Manager



The project manager leads and directs the project participants at the project level. This is the case with or without the use of BIM on projects. It is important to understand that on a project where BIM is being used, the project manager's BIM role may have to be differentiated from his or her pure project management role, which may or may not get impacted by the use of BIM on a project.

Regardless of the use of BIM on a project, the roles and responsibilities of the project manager can be broadly listed under the following two categories:

1. Project specific roles and responsibilities; and
2. Strategic or advisory roles and responsibilities (discussed in Section 3.0)

It is the project manager who should participate actively in the early decision coordination regarding usage of BIM

on the project. The decision to use BIM will involve clearly understanding the uses, advantages and challenges of BIM implementation on the project. For projects where BIM is being implemented, the roles and responsibilities of the Project Manager will be impacted by a wide range of factors about the use of BIM. This impact can be broadly defined as (as shown in Figure 1):

1. Roles and responsibilities that are driven by BIM;
2. Roles and responsibilities that drive BIM; and
3. Roles and responsibilities that are both driven by and drive BIM.

Using the framework provided by 'Appointing a Project Manager' (RICS, 2013) the roles and responsibilities of the project manager can be categorised using the 'driven by' or 'driving' BIM classification.

Figure 1: Relationship of BIM to the Project Manager's Roles and Responsibilities.

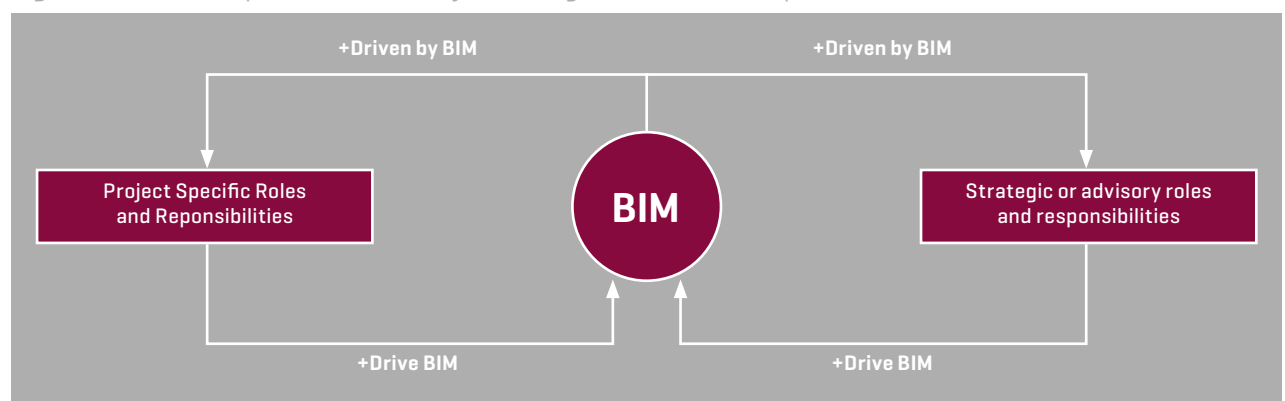


Table 1 illustrates this classification, showing how BIM adoption significantly impacts the roles and responsibilities of the project manager on a project level as well as the status of BIM adoption in the project sponsor's organisation. For example, at the project level, project managers are expected to have adequate BIM awareness so as to put the right team with the right skills together. This has to be driven by the owner's requirements, and it is essential to ensure that the BIM capabilities of the delivery network are measured and calibrated accordingly.

Perhaps the most important aspect of the roles and responsibilities of the project manager is that of managing the integration and flow of information on the project. This has a significant impact on project success and the effectiveness of BIM implementation.

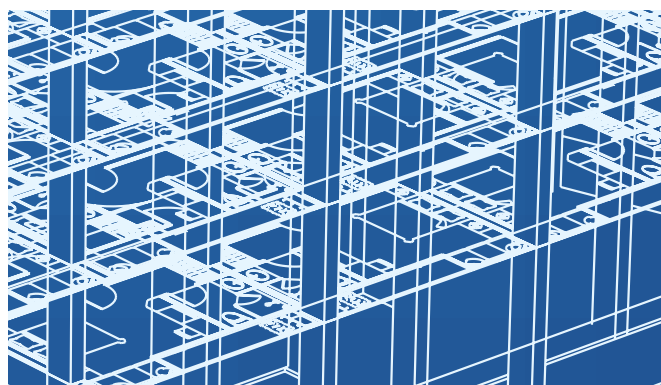
BIM can be used through the entire project lifecycle, and where project managers are concerned, acts as a catalyst in driving the following project outcomes (Montague, 2015):

- Effective and efficient project delivery;
- Briefing, including accurate understanding and adoption of BIM with realistic business casing for the use of BIM;
- Improved information capture, storage and sharing across project stages, particularly for 'handover' from design to construction, and from construction to operation;
- Improved communication, coordination and collaboration amongst the project team members;
- Accurate, timely and seamless information flows through digital transfers, reduced duplication of effort, and reduced errors;
- Better design coordination leading to better project documentation reducing inefficiencies and non-value adding tasks;
- Improved certainty in project time, cost, safety and quality parameters and an overall reduction in project risk and an overall improvement in project performance.

As the project traverses its lifecycle, the type, nature and level of usage of BIM varies. Use of BIM at the project level may, therefore, have different connotations for different project team members.

Table 1: BIM-Based Classification of Project-Specific Roles and Responsibilities of a Project Manager

#	Role	Driven by BIM	Drives BIM
1	Identifying needs and developing the client brief		✓
2	Leading and managing project teams		✓
3	Identifying and managing project risks		✓
4	Establishing communication and management protocols	✓	✓
5	Managing the feasibility and strategy stages	✓	✓
6	Establishing the project budget and project program	✓	✓
7	Coordinating legal and other regulatory consents		✓
8	Advising the selection/ appointment of the project team		✓
9	Managing the integration and flow of design information	✓	✓
10	Managing the preparation of design and construction programs/schedules and critical path networks	✓	✓
11	Advising on alternative procurement strategies		✓
12	Advising on risk management strategy		✓
13	Conducting tender evaluation and contractor selection	✓	✓
14	Establishing time, cost, quality and function control benchmarks	✓	✓
15	Controlling, monitoring and reporting on project progress	✓	✓
16	Administering consultant appointments and construction contracts		✓



Broadly speaking, usage of BIM on a project can be categorised into the following three main functions (shown in Figure 2):

- **Information Model or Model Authoring (Information Production)** – design, engineering and construction disciplines will have a heavy focus on authoring the BIM using generic or discipline specific authoring tools. A project manager will normally not author these models but must have an understanding of the general process of model authoring.
- **Information Modelling or Model Management (Information Management)** – given the number of models that may be authored on a given project, an important function will be to manage the individual models as well as the federated (combined) model. The process behind this is called Model Management and the entity that performs this function is called the BIM Manager on the project. This term and the role are both controversial as some experts feel that there is no need for a separate entity to perform this function. Nevertheless, this is an important function that must be well understood by the project manager because it is likely to have significant impact on their roles and responsibilities.

- **Model Information Extraction and Usage** – the “I” i.e. information in BIM is the most important aspect of its usage on a given project. Broadly the design, engineering and construction disciplines will rely heavily on model information extraction. However, a BIM Manager and a Project Manager will also be required to extract (and add) information from (to) the models. For example, a project manager may view a specific disciplinary model and provide comments from a coordination point-of-view.

As shown in Figure 2, these three main functions and effort expended on them varies over the life of the project. From a project manager’s point of view, while all three functions are significant, Model Management and Model Information Extraction are relatively more important.

This is because the roles and responsibilities of the project manager are largely underpinned by the three-pronged requirements of collaboration, coordination, and communication promoted by Model Management and Model Information Extraction. This, therefore, makes the interplay between Project Management and BIM Management quite significant on projects. As is seen in Figure 3, BIM Management and project management are interlinked, linking their (it is possible that the same entity may perform both these functions on a given project) functions to a significant extent.

Figure 2: BIM-related Effort expended over the Project Lifecycle.

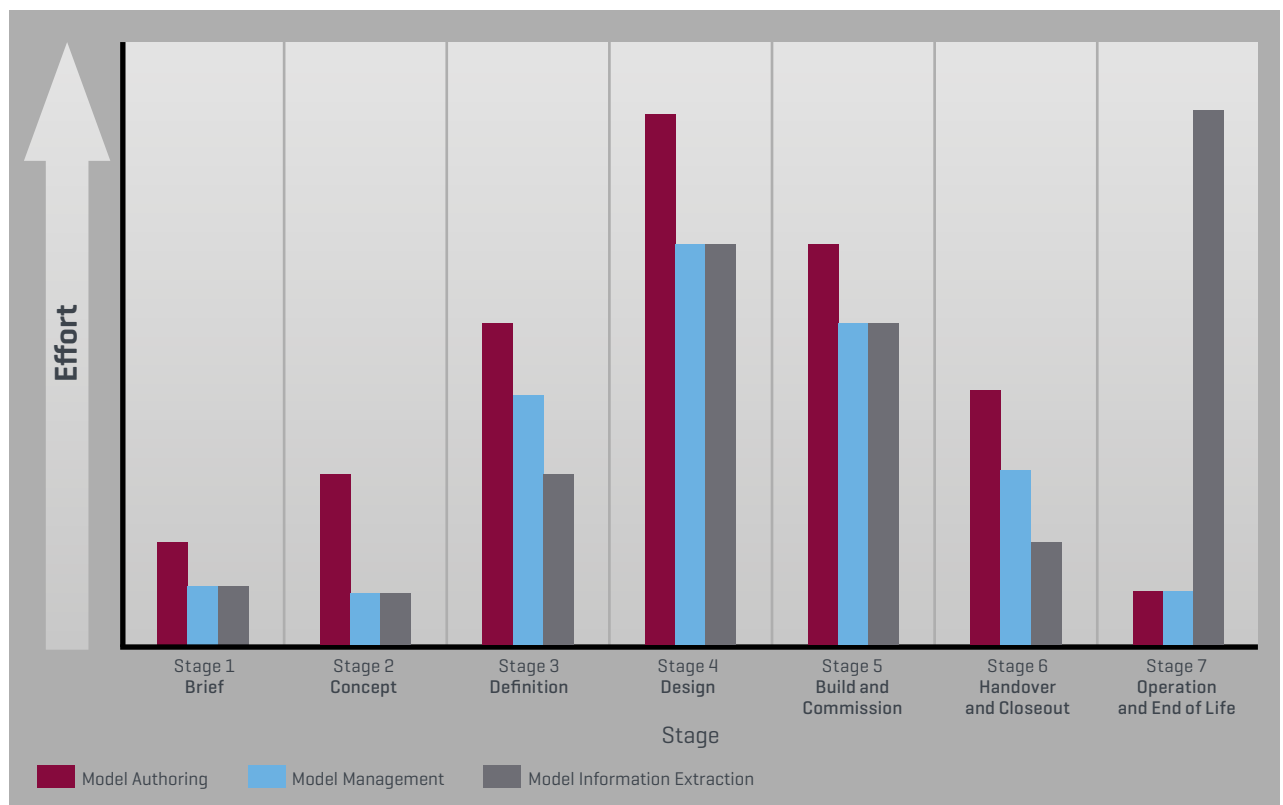
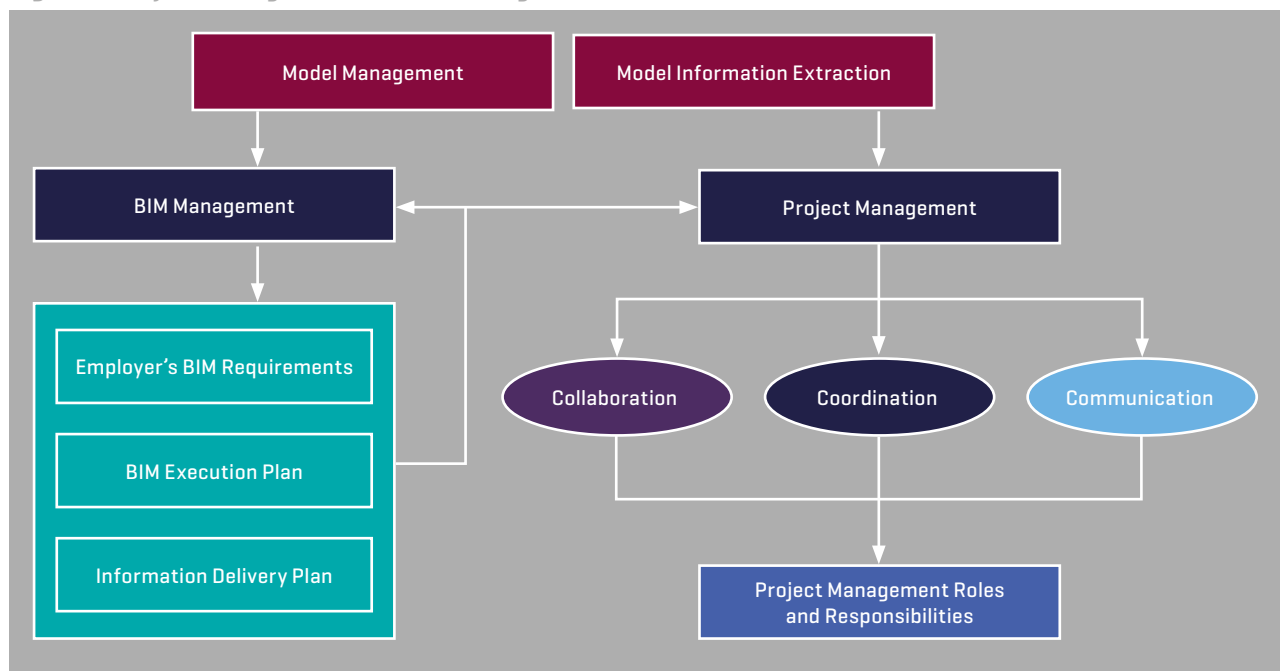


Figure 3: Project Management and BIM Management.

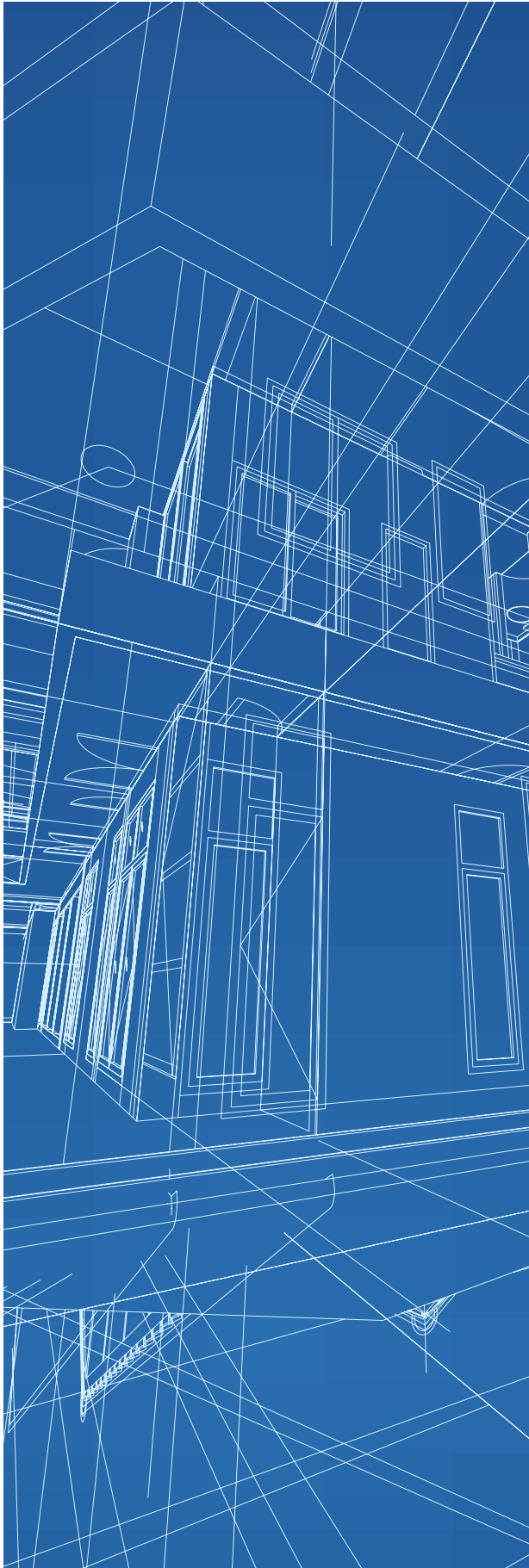
At the project level BIM Management involves the following three key aspects (British Standards Institute, 2013):

- 1. Employer's Information Requirements (EIR)** – in a way part of the project requirements, these specifically address the issue of BIM implementation on the project
- 2. BIM Execution Plan (BEP)** – this lays out the plan for meeting the project owner's BIM requirements through a structured plan that relies on the Information Delivery Plan
- 3. Master Information Delivery Plan** – also known as the Master Information Delivery Plan (as per PAS 1192); describes how the project team members will individually execute and implement the BIM execution plan by laying out a master information delivery plan. This, in turn, depends on the task information delivery plan. (British Standards Institute, 2013)

From the perspective of a project manager, projects that utilize BIM need to be managed differently. First, it has to be determined who is playing the role of the BIM Manager. A clear definition of the role of the BIM manager or the entity responsible for BIM management needs to be provided. This may just simply mean adding further responsibilities on top of the general duties of the lead design consultant on the project, or it may require hiring a specialist organisation. Nevertheless, this determination has to be made first. Where this role can also be played by the project management consultant, the linkages between the project management functions and the BIM management functions must be defined. To begin with, the project manager must ascertain answers to the following questions:

- 1.** Strategically, is the Owner's organisation ready for implementing BIM on their projects?
- 2.** How does the project brief link up with the Owner's BIM Requirements?
- 3.** Who is responsible for the BIM management role?
- 4.** Is there a process of selecting the right team members with the right BIM skills in place?
- 5.** Are the broad requirements for BIM including expected outcomes defined?
- 6.** Are all project team members aware of the BIM requirements?
- 7.** Are the protocols for producing, managing and exchanging information clearly defined (both technical and process oriented definitions)?
- 8.** Is the process of the federation of disciplinary models in place?
- 9.** Is the information content within the disciplinary models regularly checked for compliance with EIR?
- 10.** Is there a BIM Protocol and BIM Execution Plan in place and understood by the project team?

These questions can be answered with the assistance of various documents produced as part of the project documents. This exercise will allow the project manager to effectively execute their project and BIM management tasks on the project and aim for project success.



2.1 Project Managers and the BIM-Based Project Ecosystem

To understand the role of BIM from a project manager's perspective, the project ecosystem needs to be understood from a macro level. Under this worldview, at the macro level projects can be construed to consist of three layers (see Figure 4):

- 1. Project Sponsorship Layer**
- 2. Project Management Layer**
- 3. Project Delivery Layer**

Each layer has its role and responsibilities and a set of work practices. A similar ecosystem also applies to projects that do not use BIM. However, in the projects using BIM, there are some added features in the ecosystem that help to further the understanding of BIM for project management and its effects on roles and practices.

PAS 1192-2 (British Standards Institute, 2013) provides an outline of core BIM related activities from the project manager's point-of-view: This is illustrated in Figure 4.

- 1. Employer's Information Requirements (EIR):** At the top-most level, the role of the project manager in developing or participating in the development of the EIR is crucial. This goes hand-in-hand with the development of the project requirements and contains a document setting out the client's BIM objectives and deliverables. After the EIR has been defined, a Project Implementation Plan (PIP) pertaining to BIM implementation is prepared. PIP describes the project team members' information technology and human resources capability to deliver the EIR. The capabilities are defined in direct relation to the development and delivery of the Project Information Model (PIM).
- 2. BIM Execution Plan (BEP):** The project manager plays a crucial role in the development of the BIM Execution Plan that defines how the team will deliver the EIR. This in a sense becomes the driver for BIM management which in turn can help the project manager determine the project management plan.
- 3. Master Information Delivery Plan (MIDP):** This is a plan listing all the information deliverables of a project including models, drawings, specifications, equipment, and schedules. An MIDP identifies when project information is to be prepared, by whom, and using what protocols and procedures. With the help of the MIDP, the project manager can define the overall project schedule and its linkage to BIM deliverables.

Figure 5 further details the linkage between the EIR and BEP from a project manager's perspective.

Figure 4: The Project Ecosystem and BIM

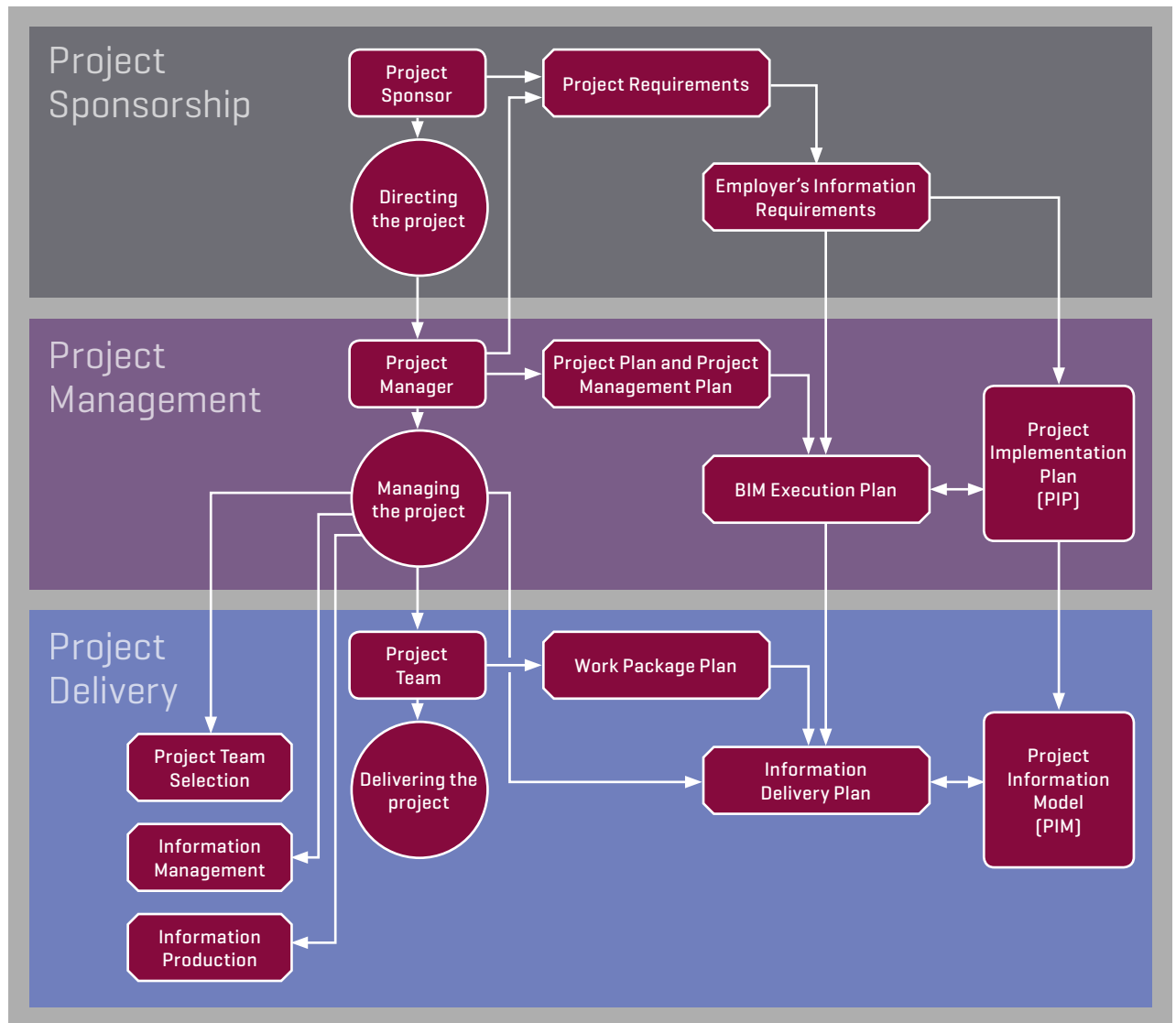
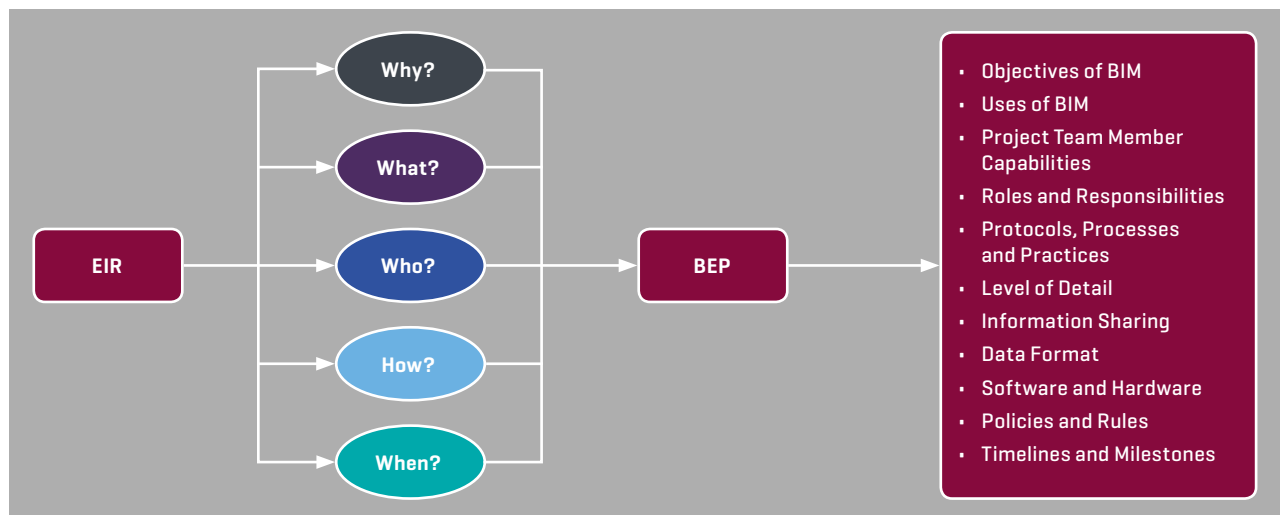


Figure 5: BIM Management Framework



At the macro level, the project manager has to participate and enable these BIM activities on behalf of the project sponsor. However, before these activities can be realised the project manager must help put together a team with the required skills set and knowledge of BIM. Once the project begins, the project manager will also be responsible for coordinating the Information Production and Information Management processes. The following sub-sections provide additional details on these important activities.

2.1.1 The Employer's BIM Requirements

The term 'Employer's Information Requirements' is used in the UK PAS 1192-2:2013. This refers to a document that defines the uses of and requirements for BIM from the Project Sponsor's perspective. Broadly this document consists of the following details:

Management

- **Objectives of using BIM to answer the question of 'why?'**
- **Standards:** This section lists the BIM-related standards (mostly national standards) to be followed by the project
- **Roles and Responsibilities:** the allocation of roles and responsibilities associated with the management of the model and project information
- **Planning the Work and Data Segregation:** Clear roles and responsibilities of various project team members to be designated according to the work packages or trades
- **Security:** In this section, the data security measures to be adopted for all BIM data are listed
- **Coordination and Clash Detection Process:** The process to be followed for developing the federated model for coordination and clash detection is provided in this section
- **Collaboration Process:** This section outlines the BIM-based collaborative process to be adopted by all team members
- **Health and Safety and Construction Design Management:** This section outlines the system by which BIM supports Health and Safety aspects of the project and more importantly how the construction process is supported

- **Systems Performance:** Any IT systems constraints specific to the project are outlined in this section
- **Compliance Plan:** Compliance issues such as integrity of the model and other data sources will be maintained
- **Delivery Strategy for Asset Information:** This defines the data format, standard and protocol to be used to deliver the Asset Information for the use phase and facility management

Technical

- **Software platforms:** Software tools to be used in the project for BIM model-authoring, federation, and other BIM related tasks
- **Data Exchange Format:** This defines the formats used to deliver data at various identified data drops
- **Coordinates:** These documents provide and promote adoption of a common coordinate system for all BIM models authoring
- **Level of Detail (LOD):** This section defines the LOD levels to be followed for various models
- **Training:** This informs all the project team members about the BIM related training to be provided by the project sponsor

Commercial

- **Data drops and project deliverables:** Content of data drops and alignment of these data drops to work stages is provided in this section
- **Clients' Strategic Purpose:** This section clearly outlines the strategic purposes for which the project sponsor intends to use the model
- **Defined BIM/Project Deliverables:** List of BIM based deliverables is given
- **BIM-specific competence assessment:** This section lists the BIM capabilities and experience the project team members must demonstrate to work on the project

2.1.2 BIM Execution Plan (BEP)

For the project manager, the BIM Execution Plan is a crucial document as it helps to link the BIM implementation on the project with the overall project management plan. Most questions that the project manager will need to answer will be contained in this document. It documents the processes and procedures required to achieve BIM objectives that ultimately allow the accomplishment of project objectives. In Table 2, the contents of a typical BEP as provided in two popular BEP templates are shown. The BEP consists of the following key items:

1. BIM use cases for each stage of a project and its integration with project management functions;
2. BIM deliverables for each BIM use case;
3. Model author and users for each BIM deliverables;
4. Model elements, level of details and attributes for each BIM deliverable;
5. Process for BIM creation, maintenance, release and collaboration for each BIM use case; and
6. Hardware and software environment.

2.1.3 Master Information Delivery Plan (MIDP)

The project team members complete a pre-contract BEP which after the contract award is replaced by a post-contract BEP. The post-contract BEP consists of the MIDP which is derived from a series of Task Information Delivery Plans (TIDP). The collation of the TIDPs helps prepare the MIDP that gets connected to the BEP and EIR. Figure 6 shows the MIDP and its relation to the pre and post contract BEP and TIDPs.

Figure 6: Master Information Delivery Plan

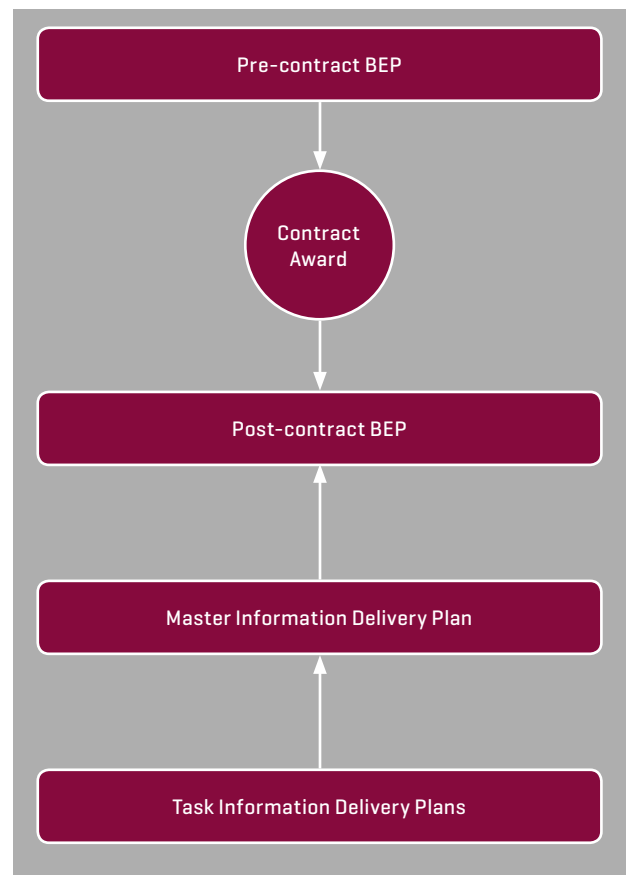


Table 2: Main Contents of BEP

Guidance source	BEP Contents
Penn State University's BIM execution planning guide	<ul style="list-style-type: none"> define high-value BIM uses during project planning, design, construction and operation phases use process maps to design BIM execution, clearly showing process steps, roles and responsibilities of project team members, and input and output from each step define the BIM deliverables in the form of information exchanges, information encapsulation, model progression and model quality develop a detailed plan to support the execution process via identification of major deliverables.
Singapore BIM Guide	<ul style="list-style-type: none"> define roles and responsibilities for model creation, maintenance and collaboration across the project life cycle phases clearly define the process of BIM implementation identify resources and services that may be needed define a project management plan for BIM implementation.

2.2 BIM, Project Management Functions, and the Project Lifecycle

The project manager will not normally be involved in model authoring, but it will be their role to ensure that all the key elements required to achieve a successful BIM project are in place. The delivery process that underpins the development of the Project Information Model (PIM) consisting of the Design Intent Model and the Virtual Construction Model must be managed as part of the project management process for the project (Figure 7).

Ultimately the project manager must oversee the delivery process of the Asset Information Model (AIM) at the handover stage of the project. Therefore it is important for the project manager to understand how their BIM and project management roles spread across the project life cycle. This will ensure that the project manager is asking the right questions and confirming that activities and functions are implemented at the right time by the right set of project team members. There will be some crosscutting activities that the project manager will have to ensure irrespective of the life cycle stage that the project is going through. Table 3 lists the BIM roles of a project manager linked to the project life cycle.

Figure 7: Development of the Building Information Model

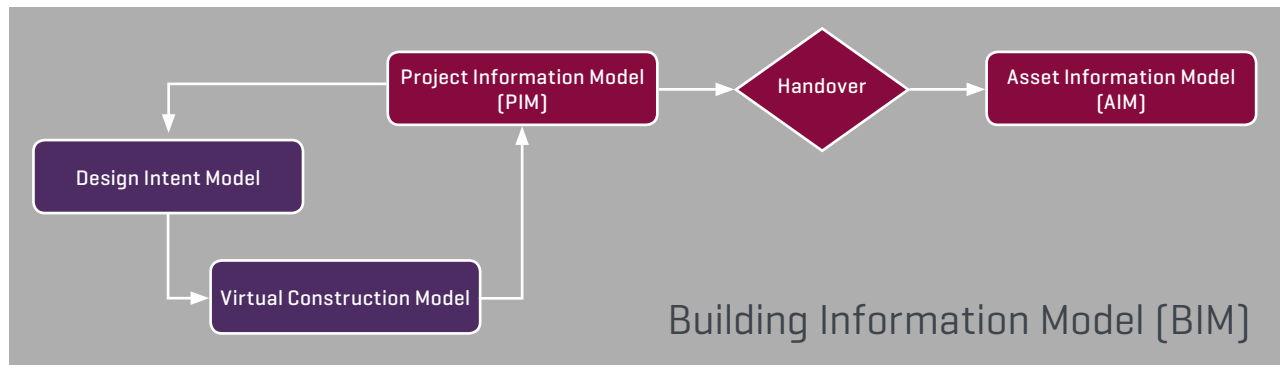


Table 3: Overview of a project manager's BIM role over the project lifecycle

Stage	Project Manager's BIM Role	BIM applications
Briefing, Inception and Pre-construction	Feasibility analysis [technical and financial]	<ul style="list-style-type: none"> BIM adoption question Challenges to BIM adoption Concept-stage BIM
	Value engineering	Options selection using BIM, Conceptual Estimating Modelling, Energy Analysis, Design Analysis
	Design management	BIM information exchange, 5D (rapid cost feedback to design changes), BIM Coordination
	Risk analysis and safety	Simulation, Virtual Reality [VR] and Augmented Reality [AR]
	Scheduling	4D Modelling
	Constructability analysis	4D Modelling, virtual mock-ups, VR and AR
	Procurement [design and construction]	BIM skills and capability mapping, BIM enabled Supply Chain Management, Constraint Analysis
Construction	Phasing and prototyping	4D
	RFIs and issue resolution	BIM information exchange, BIM coordination
	Change management	BIM information exchange
	Monitoring and control	4D and 5D, Constraint Analysis, Progress Tracking and Production Planning
Project closure	Contract and financial closure	Record model
	Project closure	Record model, Asset Information Model
	Handover	Record model, BIM for FM, Asset Information Management

2.2.1 BIM during the Brief, Concept and Definition Stages

During the concept design phase, the asset starts to emerge from a list of requirements into a proposed physical shape. In this phase, the designers are experimenting with the massing, volumes, and positioning of different functional spaces and entities. During this time the project manager must ensure that the overall Owner's Project Requirements and Employer's Information Requirements are in congruence with the concept that is being developed by the project team.

Although the list of requirements also known as the basis of design gives a good insight to the approximate capital cost, there are some (BIM-based) tools that can help in the quick evaluation of different design options to choose the most efficient concept design on the parameters of cost and sustainability.

These tools help in evaluating different design options on the criteria of cost and enable the linkage of different cost parameters at a very high level to different design and space parameters. Similarly, there are multiple BIM-enabled sustainability and energy analysis tools that help evaluate the different design and massing options for energy efficiency and sustainability. Based on the project requirements, the project manager has to ensure that these tools are used appropriately and that the required results are shared with the project team.

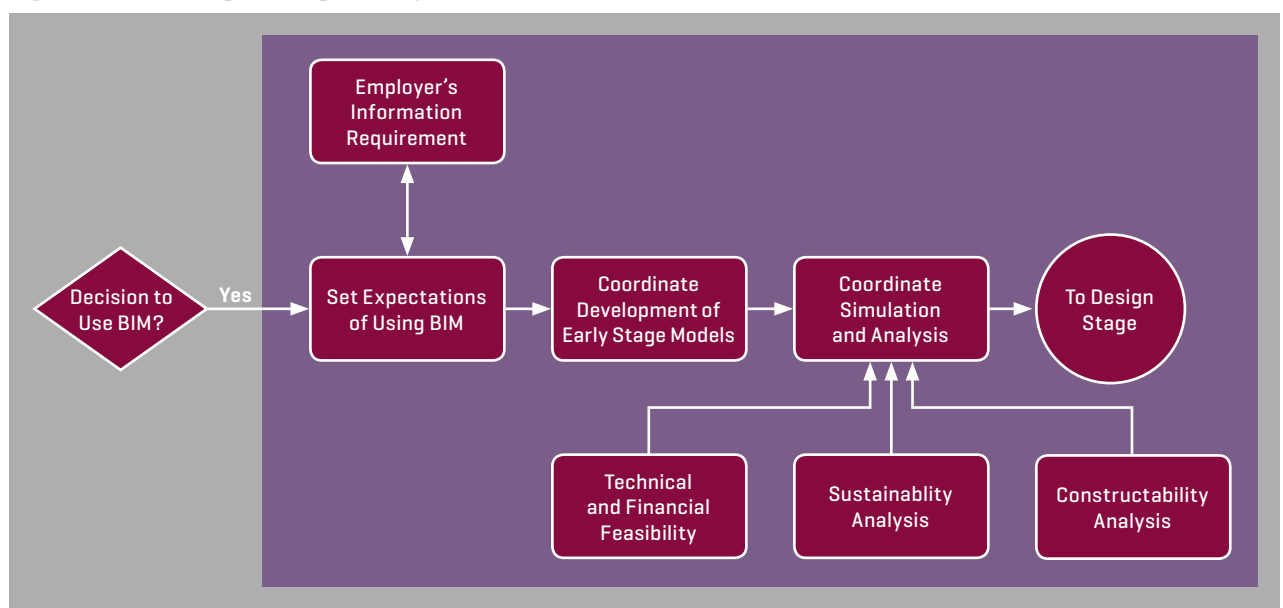
Implementation of these technologies in this phase is subject to the availability of subject matter experts and the affordability of using these tools. A project manager

in this phase has to make prudent decisions on how to best inform the design on form, cost and energy aspects based on the constraints mentioned above along with the time available at hand to finalise a concept design. BIM becomes a very important modelling and analysis tool that can provide the project team with access to what-if simulations. All decisions on affordability, budget and cost should be made in the context of lifecycle costing for the asset and not on a pre-determined budget set aside for design phase. Alongside that, it is recommended to do a proof of concept to ensure that the desired output at the expected level of detail is available before implementing proceeds to downstream steps.

Project managers have a key role to play in defining the BIM Execution Plan during this phase. The roles and responsibilities of the different stakeholders need to be determined for the BIM process. The BIM workflows in the form of process maps need to be created so that the entire team can follow these during implementation. Furthermore, information handover details such as the level of detail at which the models should be handed over by the design team to the construction team also need to be determined. The means and methods of collaboration and coordination need to be chalked out.

Some projects have failed to realise the value from BIM where the activities mentioned above have not been done. In these cases, instead of adapting to newer project deliveries, design managers have resorted to the standard protocol of delivering a set of drawings at certain design milestones and project managers have resorted to issuing change orders.

Figure 8: BIM during Briefing, Concept and Definition Phases



2.2.2 BIM during the Design Stage

The intent of this phase is to provide an error free design which, once committed by the project team, will not trigger any (many) changes due to constructability issues. This requires upfront collaboration between the design team and the engineering team. Early involvement of the constructors is an option to ensure construction experts have had the opportunity to review the design and provide cost and constructability input. This process requires enhanced collaboration, coordination, and communication made possible by BIM along with innovative project delivery methodologies such as Integrated Project Delivery (IPD).

Project managers are most effective in this phase if they focus on Integration Management (the processes and activities needed to identify, define, combine, unify, and coordinate activities within the project). BIM is increasingly becoming a powerful tool for project management during this stage. The design is handed over at a certain level of detail/development (generally LOD 300) of BIM, and then the constructor details it further to the next level of detail/development (LOD 400), a process through which the design is vetted out for constructability and coordination issues. Owners benefit the most from an upfront collaboration between the design team and construction team orchestrated by BIM. Obviously, appropriate contract language and financial incentives should be in place to encourage this collaboration between design and construction teams.

2.2.3 BIM during Construction and Commissioning Stages

The use of BIM changes over the project lifecycle. In the design phase, it plays a role in design analysis, coordination, and (model) authoring. The role transitions during the construction phase to assist in activities such as fabrication, supply chain management, building layout, formwork planning, safety management, quality management, and other construction management functions, the lowest hanging fruit being coordination.

BIM Coordination has now become a norm in many of geographies in the world, especially for medium to large size projects. This is a major activity that a project manager would be involved in at this stage. It is important that BIM coordination is integrated into the project execution workflow of the project so that the following pitfalls are avoided:

- Models being coordinated, but the building still being built from the drawings;
- Model coordination changes not being incorporated into the project documents including drawings;
- Model coordination occurring in a disjointed fashion to the design schedule and done too early when design is still evolving, resulting in the model coordination playing catch-up and the design signoff not being defined;

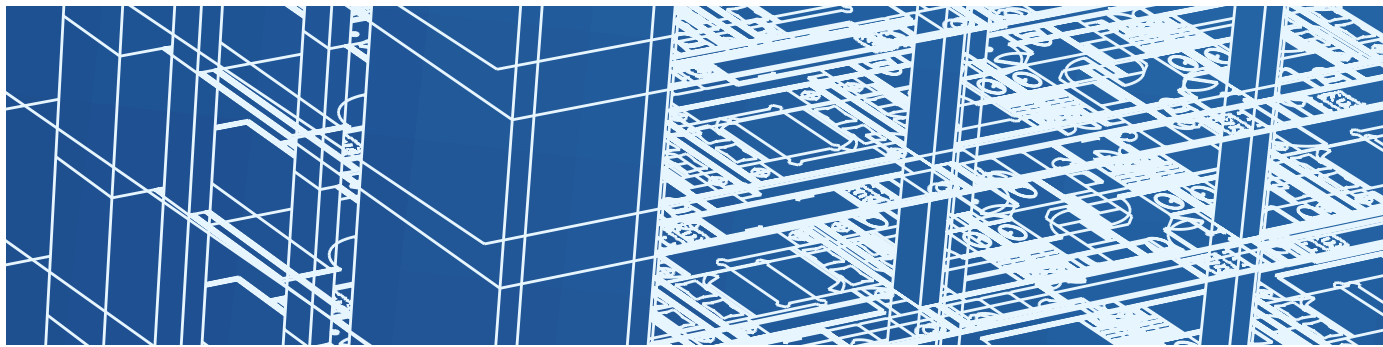
- Model coordination occurring in a disjointed fashion to the construction schedule and done too late with the result that the construction schedule does not include coordination as a pre-requisite to shop drawings or field layout;
- Not all systems modelled as defined in the EIR leading to fragmentation in the design and construction processes;
- Entity installing the system in the field does not carry out the modelling or does not take ownership of the model;
- The level of detail of models not adequate and out of sync with the BEP.

Project managers have an important role to play in avoiding the issues listed above that could be solved virtually through BIM. When interacting with stakeholders, project managers need to speak the common language and should have a unified vision of the intent to use BIM on the project. This is made possible by developing a BIM execution plan collaboratively and treating it as a live document and updating it continuously with consensus. An important thing to keep in mind while developing processes for BIM Implementation is not to develop new processes to implement BIM but to modify existing processes like design delivery, shop drawings, and procurement, field layout, etc. and identify where BIM fits in. Additionally, what also helps is to define process metrics like “All design drawings generated from BIM”, “All shop drawings generated from Coordinated (Clash Free) BIM” etc. This is where BIM transitions from Building Information Modelling to Virtual Design and Construction. If this approach is not adopted, BIM implementation generally fails on projects.

BIM has evolved from a primarily design authoring tool to a tool that assists constructors in various processes during the execution phase of projects. However, the use of BIM during the construction phase is still limited. Unlike the manufacturing sector where the industry integrates three-dimensional modelling into their PLM (product lifecycle management) enterprise applications, in construction, this is yet to be done. This can be attributed to the vertically integrated nature of the manufacturing industry compared to the more fragmented nature of the construction sector.

The construction industry has a variety of ERP (Enterprise Resource Planning) applications and once integrated to that, the true value of BIM can be realised when it comes to procurement, planning, billing verification and earned value analysis. However, BIM technology solutions available in the market predominately cater to one aspect or another, and so we are yet to see true BIM enabled ERP solutions in the marketplace.

Until then, project managers will have to manage these project functions using the more traditional approach in which information is extracted from the models in a fragmented fashion and used in processes that are not



model-centric. Project managers are the powerhouses of knowledge and hold the key to creating such BIM-enabled ERP. Nevertheless, the benefits seen from independent implementations of BIM are significant; therefore it is important that a project manager is aware of how they can execute them effectively.

Project Managers should acknowledge that different BIM uses are at different stages of maturity. Using the five phases of Gartner's Hype Cycle (Innovation Trigger, Peak of Inflated Expectations, Trough of Disillusionment, Slope of Enlightenment, and Plateau of Productivity) is a good frame of reference to understand at what stages of maturity the different BIM uses stand. Understanding the maturity of BIM usage helps project managers to determine their level of engagement. For BIM uses that are in the first three phases of maturity, namely, Technology Trigger, Peak of Inflated Expectations and Trough of Disillusionment, the project managers play more of a 'promoter' role where they take the calculated risk of providing opportunities to try and test the technology and assess its benefits. The scale of implementation is localized to a small aspect of the project and is typically done in parallel to established processes and technologies.

Project management is critical in the context of BIM uses in the slope of the enlightenment phase. These BIM uses have proven technology aspects and implementation is subject to how effective project managers are in getting the buy-in of the stakeholders and building a process that integrates the BIM use to deliver value to the project. As the BIM use enters the Plateau of Productivity, the project managers don't have to do any work getting the buy-in of the stakeholders. Instead, their focus is on attaining stakeholder alignment on how best to structure the organization of the project and build processes to maximize the efficiency of BIM usage. Keeping these general guidelines in mind, project managers can ensure that their involvement in various BIM uses matches with the maturity level.

General Contractors have also started to use BIM for visual planning. What initially started as an effort to link 3D objects to construction activities to visualise schedules is now evolving into a more powerful production planning tool. In this 3D driven production planning process the

duration of the scheduled activity is validated against the duration derived from the model when the construction productivity is linked with the quantity from the 3D model. As part of the collaborative visual planning, BIM is being used to visualize constraints such as pending issues, missing information, shop drawing approvals, procurement constraints, spatial constraints, etc.

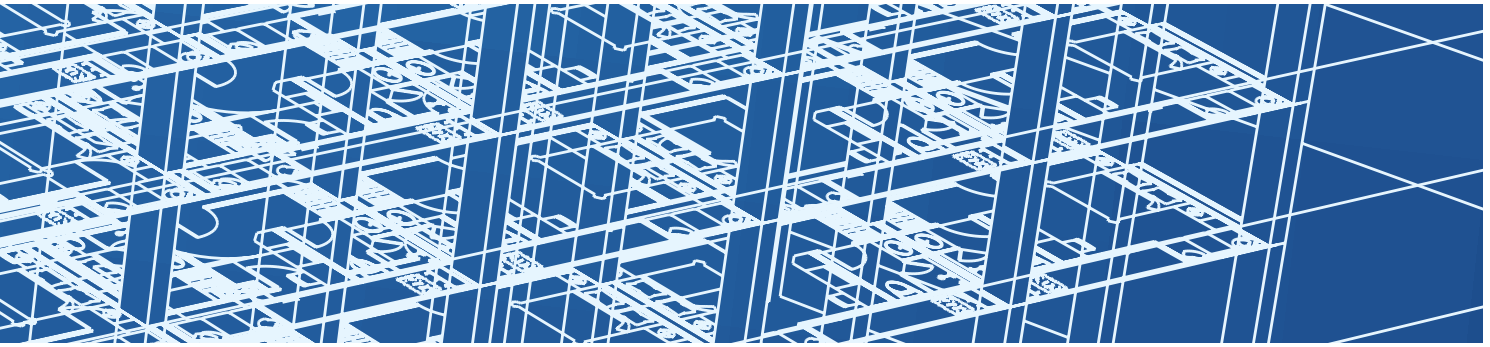
BIM technology is now available to access via iPads and handheld devices that construction workers can take onsite and check as 'built against-as-modelled'. This acts as a quality check for the built product.

BIM is also being used heavily by subcontractors to fabricate construction elements without any manual interventions like using Sheet Metal for HVAC or to layout points in the field directly from the model using modern surveying equipment that imports points directly from the model. This has significantly increased the accuracy of fabrication and installation and has minimised material waste and reworking. Information is also now extracted directly from the model to the total stations to layout points in the field in order to assist with accurate layout.

BIM is also making its way into the supply chain management domain where it acts as a visualisation tool to check the status of the material. It also helps to allocate and schedule the model/scope into individual work packages (e.g. concrete pours, erection sequence in steel, spools in plumbing, etc.). This helps in determining how the element will be shipped or built on-site. This information then makes its way into BIM-enabled planning and scheduling.

BIM is being seen as the data repository where asset information is being stored for it to be migrated to the owner's facilities management systems or for it to be used for building performance monitoring by linking it with Internet of Things (IoT) devices.

All these different applications of BIM in construction are geared towards increasing the productivity in the field, minimising rework and building a high-quality product. Project managers are the key agents who can guide these BIM technologies making their way from experimentation to effective implementation, thereby reaping the benefits for their projects.



2.3 Communication, Coordination, and Collaboration

The design and construction of assets in the built environment is a complex and challenging undertaking. As early as 1916, Henri Fayol highlighted coordination as an important management task in all spheres of business activity (Fayol, 1949). Much later, (Higgin and Jessop, 1965) reached a similar conclusion in the built environment domain by stating that *“Looking at the building process, we can distinguish three main functions. Two are obvious: design and construction. The third is coordination”*. Figure 9 shows these three functions and their inter-linkages and interdependencies. While this may be an oversimplification of the design and construction process, it does highlight the importance of communication, coordination and collaboration.

Notwithstanding earlier wisdom shown to have been assimilated, construction industry treats the design, construction and coordination functions with a different set of priorities (Ahmed and Saram, 2001). It is a well-known fact that coordination is given a low priority in the overall planning of a construction project. This seemingly upside-down scenario is paradoxically opposite to the importance that design has in the overall success of the project delivery process.

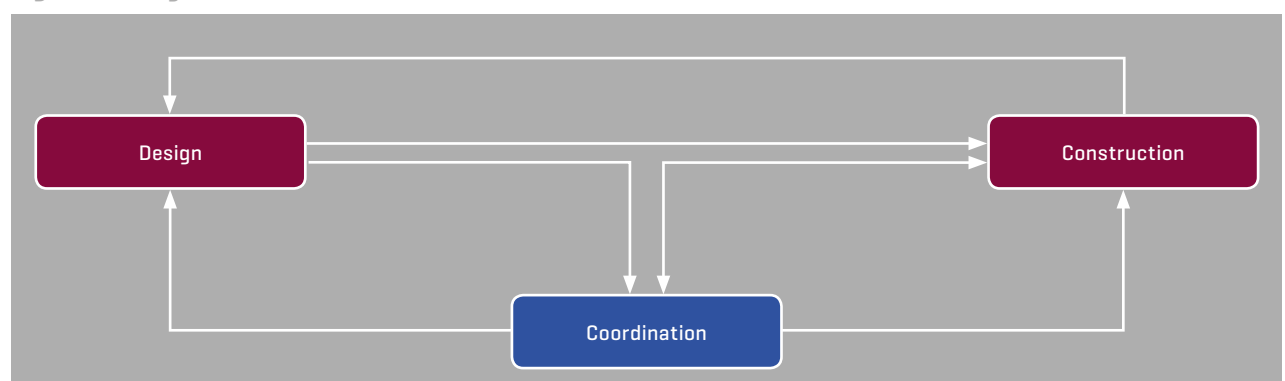
Researchers have documented that errors have 50% of their origin in the design stage and 40% in the construction stage as (BRE, 1981). Others have also reported similar wastes and inefficiencies induced by inefficient design and construction processes (Andi and Minato, 2004), (Daoud, 1997). Many of these inefficiencies can be eradicated via improved communication, coordination and collaboration. The responsibility for this improvement lies squarely on the shoulders of the project manager. Many will argue that communication is fragmented, true collaboration between project team members limited. Further coordination is often considered only when something goes wrong, and the general understanding is that design mistakes will be corrected in the field (Eastman et al., 2011b). This is where BIM can introduce a significant change by enhancing all three aspects of the project—communication, coordination, and collaboration.

Project Managers can use BIM to orchestrate improved communication, coordination, and collaboration on projects. This can be accomplished by deploying the following two mechanisms, which project managers should promote proactively:

1. Common Data Environment (CDE)
2. BIM Collaboration Format (BCF)

These two concepts are explained in the subsections directly following.

Figure 9: Design, Construction, and Coordination



2.3.1 Common Data Environment (CDE)

The idea of CDE was originally proposed in BS 1192 (British Standards Institute, 2007) and PAS1192 (British Standards Institute, 2013). CDE provides a single source of information for any given project, used to collect, manage and disseminate all relevant approved project documents. Creating this single source of information facilitates collaboration between project team members and helps to avoid duplication and mistakes. From a project manager's perspective, CDE provides the following benefits (Boxall, 2015):

- Reducing the time and effort required to check, version and reissue information;
- Extracting selections of the latest approved data from the shared area;
- Reducing coordination checks (ensuring models are correct, which are a by-product of the detailed design production process);
- Reuse of information to support construction planning, estimating, cost planning, facilities management, and many other downstream activities; and
- Reducing the time and cost of producing coordinated information.

The CDE can be stored on a project server or extranet. While selecting a platform for the implementation of CDE, the project manager must consider the features listed in Table 4.

2.3.2 BIM Collaboration Framework (BCF)

BIM Collaboration Format (BCF) is an open standard for exchanging coordination information to enhance collaboration between the project team members (Stangeland, 2011). It is an initiative of buildingSMART. Using extensible markup language (XML) BCF provides a standard protocol for communicating a model-driven environment. Figure 10 shows the process that can be used with BCF to identify and resolve coordination issues and clashes in the model data.

Table 4: Some Features of the CDE platform

Feature	Details
Workflow Management	Ability to automate, manage and report; Request for Information [RFI] Management
Model Management	Version control, model comparison, model checking, model merging and federation, model check-in/check-out
Model Serving	Compatible formats, model navigation, partial model publishing, and model querying
Communication	Email, instant messenger, BIM Collaboration Format [BCF], notification and audit trail
Coordination and Clash Prevention	Model navigation, viewing, search and selection, mark-up, reporting, definition of rules, combination of disciplinary models, soft and hard clashes, discipline and location identification of clashes, compatibility with BCF and openBIM
Phasing and Prototyping	Integration with scheduling software, what-if simulations, tracking, monitoring and control, modelling of plant and machinery
Facility Management	Data management, reporting, information extraction, compatibility with FM systems and processes
System Administration	Archiving, customization, data/model security, remote access, versioning, updates
Use Management	Profiles, access control, security, audit trail, data locking, upload and download access and change management

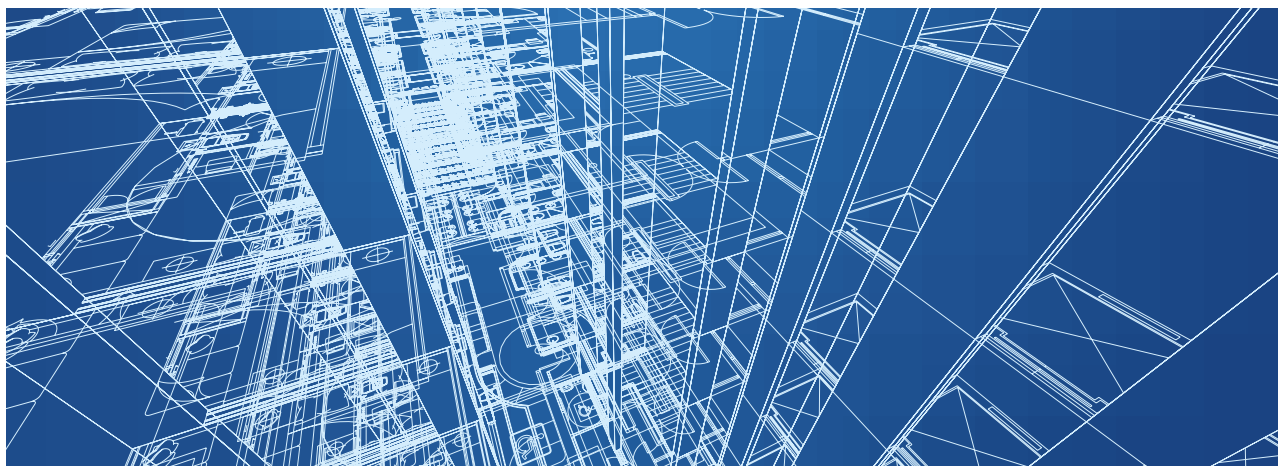
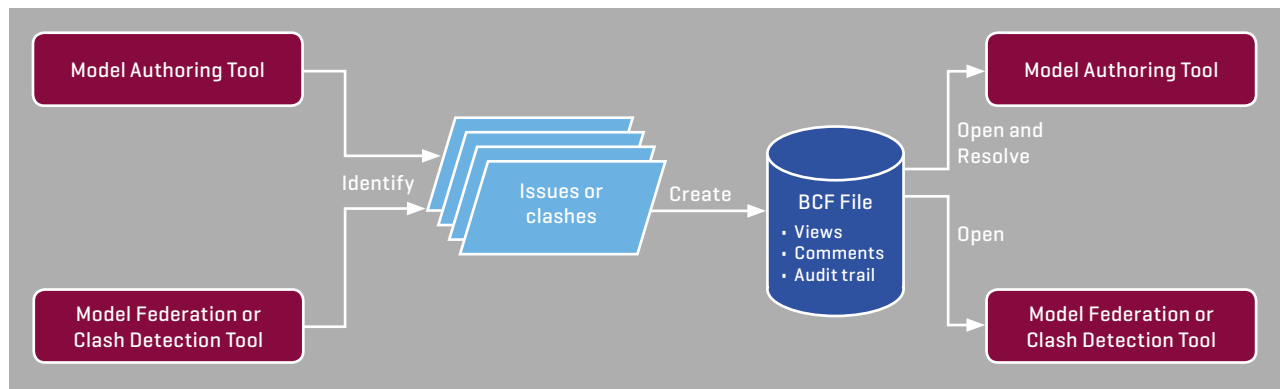


Figure 10: BCF based clash prevention and resolution process

Any team member can initiate the coordination and collaboration process. For example, the project manager can view the federated model combining all the disciplinary models to identify issues. Similarly, a designer with the model authoring role can open the federated model in a model-authoring tool and identify clash or coordination issues. These can then be captured in the BCF format and shared with the respective project team member. The BCF file is a lightweight file that connects the issue back to the required modelling elements but disconnects from the main model file. The recipient of the BCF file can seamlessly open the BCF file(s) to open, view and resolve the coordination issues identified by the originator. This process can be repeated to resolve outstanding issues. Rather than sharing the entire model file, the BCF uses a standard protocol to share the coordination information in a simple manner.

2.4 Implications of BIM for Project Managers

Project management knowledge is globally disseminated via the standards of organisations such as the Project Management Institute, Association for Project Management, and International Project Management Association. These sector-agnostic standards have also been further refined for the built environment sector. For example, “Construction Extension to the PMBOK Guide, Third Edition” (Project Management Institute, 2007) adapts certain aspects of the project management body of knowledge to sector-specific practices.

As BIM implementation becomes more pervasive in built environment projects, there is a need to refine the standard knowledge base of project management further to incorporate high-level principles. Table 5 provides a summary of the implications of BIM adoption on the project management knowledge areas as defined in the PMBOK Guide.

Table 5: Influence of BIM on Project Management Knowledge Areas

PMBOK Knowledge Areas	Influence of BIM
Project Integration Management	Development of the project charter and project management plan in sync with the BIM Execution Plan; develop integrated change control with BIM
Project Scope Management	Integrate BIM Execution Plan with Scope Definition; develop a Scope Control mechanism
Project Time Management	Incorporate standard processes and practices of 4D simulation, phasing, and prototyping; interface of project schedule and the BIM implementation plan
Project Cost Management	Incorporate standard processes and practices of quantity take-off, estimating; link cost assemblies with model objects to generate estimates
Project Quality Management	Interface of model quality management plan with the overall project quality plan
Project Human Resource Management	Coordination and communication protocols, training, and competency mapping about BIM
Project Communications Management	Collaboration, coordination and communication protocols
Project Risk Management	Accuracy and certainty in time, cost, and other project parameters
Project Procurement Management	Supply chain integration, Quantity take-off, estimating
Project Stakeholder Management	Visualisation, Collaboration, Information Sharing

2.5 Defining Metrics for Successful BIM Implementation

The starting point of a BIM Execution Plan is to define the intent of using BIM on the project. The next step is to come up with a measurable goal to check if what was set out to be achieved using BIM was accomplished or not. It is imperative that any BIM implementation has a measurable goal in addition to intermediate/process goals that help us measure the incremental change and progress. The role of project manager is crucial in defining this measurement framework and using it as a tool to manage progress. Here are some examples of some of the measurable goals:

1. Design Authoring:

- a. All design drawings generated from BIM

2. BIM Coordination:

- a. Zero RFIs or Change Orders due to spatial conflicts between trades

3. Field Layout:

- a. All Shop Drawings or Field Layout drawings generated from BIM information
- b. Zero field errors in placement of building elements

4. BIM for Costing:

- a. % of Cost Estimate derived from Model

5. BIM for Facilities Management:

- a. % of Assets in Facilities Management System derived from BIM
- b. % of Asset Information derived from BIM

6. BIM for Planning:

- a. Zero schedule issues related to sequencing between trades

2.6 Changes in Contractual Arrangements

With BIM adoption, some adjustments to the contractual arrangements between various parties involved in a project are needed. In most standard forms of contracts used globally, there is no specific coverage of BIM. These contracts do not explicitly or implicitly allow or prevent the use of BIM in any phase of the project. The most accepted procedure to contractually incorporate BIM implementation on a project is via the incorporation of an addendum or protocol specifically relating to BIM, making it binding on the parties entering into the contract. Three well-accepted BIM addenda currently available are as follows:

- ConsensusDocs 301 Building Information Modelling (BIM) Addendum;
- CIC BIM Protocol; and
- AIA Digital Practice Documents consisting of:
 - AIA G201–2013 Project Digital Data Protocol Form
 - AIA G202–2013 Project Building Information Modelling Protocol Form
 - AIA E203–2013 Building Information Modelling and Digital Data Exhibit; and
 - AIA C106–2013 Digital Data Licensing Agreement.

As the project delivery shifts from work practices that rely on 2D static information to model-centric information sharing and collaboration, a new set of perceived challenges appear. Some of the relevant questions in this context are:

- What risks are induced by sharing models among project team members?
- Is the BIM manager exposed to additional liability?
- Is there a change in the allocation of responsibility and liability exposure among project team members?
- How should intellectual property rights and copyright issues be addressed?
- What changes are needed to the contracts?

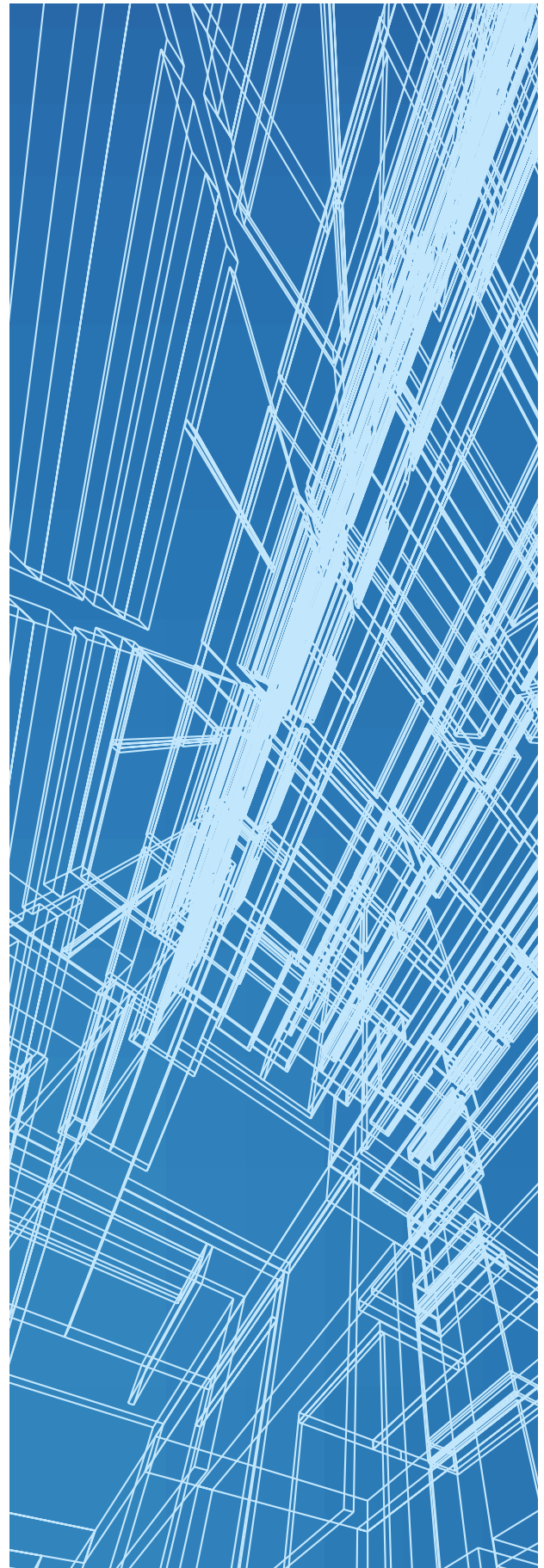
2.7 Assessing BIM Maturity at The Project Level

Measuring the 'maturity' of BIM implementation at the project level is critical. The project manager requires a thorough knowledge of the current BIM maturity models to assess the capability and maturity levels of the project delivery network, especially those of the project sponsor and key project team members.

There are a plethora of frameworks for assessing BIM maturity internationally. Amongst the most recognisable assessments are the National BIM Standard Capability Maturity Model (NBIMSCMM) (National Institute of Building Sciences, 2015), which was the first system to be developed, the BIM Maturity Matrix (Succar, 2009) and the Virtual Design and Construction (VDC) Scorecard (Kam, Song and Senaratna, 2017). Each has a unique perspective on BIM performance. In the UK, the CPlx BIM Assessment Form provides a way to measure the BIM capabilities of the project delivery network. This CPlx BIM Assessment Form uses the: (a) gateway questions (b) 12 areas of BIM; (c) BIM project experience; and (d) BIM capability questionnaire to make the assessment. Primarily the two levels of assessment are as follows:

1. Assessment of the organisation focuses on assessing its vision, mission and goals linkage with organisational strategy; the level of top management support; the level to which BIM is championed in the organisation; current processes and practices; and hardware and software support; and learning and development. This framework provides feedback at the organisation level, without necessarily assessing any of its individual projects.
2. Project assessment, on the other hand, focuses on evaluating the BIM capability and experience of the project team members; defining the uses of BIM; availability of the BIM execution plan; clear definitions of processes and practices about model management, data exchange, interoperability and level of development; and commercial and contractual arrangements.

Using any of the systems briefly described above, the project manager can undertake an assessment of the BIM capabilities and maturity of the proposed project team.



3.0 Strategic Issues Pertaining to BIM and Project Management

Project-based organisations, be they real estate developers, infrastructure developers, construction organisations, design and engineering consultants, project management consultants or a myriad of other organisations directly involved in the delivery of built environment projects, must consider BIM implementation at the organisational level. One-off, opportunistic BIM implementations at the project or discipline level are sometimes sufficient to get an organisation off the ground, but such attempts have eventually failed or have provided limited benefits to the organisation (Oakley, 2012; Dainty et al., 2015). Therefore it is crucial that these organisations consider BIM implementation as a radical change that leads to business transformation rather than project-centric phenomena alone. Project managers can play a significant role in the organisational shift and transformation process induced by BIM. They can help develop a plan for syncing the organisational strategy, project strategy and BIM strategy within the organisation. Table 6 shows how BIM influences the strategic and advisory roles and responsibilities of the project manager.

3.1 BIM Adoption Decision

Some experts couch BIM adoption as a 'no-brainer'. However, given the implications of BIM adoption for an organisation, this method of thinking is flawed; organisations failing to do a careful analysis of the adoption decision may end up stopping mid-way or finding significant hurdles in their BIM adoption journey.

Project managers are well placed to help an organisation conduct a careful analysis of the decision over BIM adoption. Even organisations that undertake one-off BIM projects may have to make this organizational decision eventually. For the project manager, the first order of business is to develop a clear value proposition and a business case for the adoption of BIM for a given organisation.

Table 6: BIM Based Classification of Strategic and Advisory Roles and Responsibilities

#	Role	Driven by BIM	Drives BIM
1	Advising on methods by which to engage with the construction industry [procurement of design and construction]		✓
2	Establishing an overall development program with intermediate milestones for key activities for procurement, design, and construction. This may also include an indication of key interfaces and constraints, such as planning permission		✓
3	The definition and development of client organisation structure	✓	
4	Identification of key stakeholders and managing their input [e.g. FM, security, it, etc.]	✓	
5	Advising on statutory requirements, such as planning permission and how to obtain it	✓	
6	Assisting with strategic decision-making and in the development of the project brief and a project execution plan	✓	✓
7	Reviewing and commenting on emerging design proposals to identify if they remain consistent with the project brief	✓	✓
8	Assisting in the handover process at completion	✓	

Fundamentally, the project manager can help a project-based organisation answer the important question “Why is the organisation looking to introduce BIM?”

The answer to this question will, of course, be dependent on the organisation’s vision, mission and strategy. Since each organisation is different, the business case for BIM will have to be derived by contextualising it to the specific set of circumstances. However, the project manager can focus on the following key issues when helping an organisation develop an answer to the BIM adoption question:

1. Organisation’s business plan;
2. Nature and type of projects;
3. Business ecosystem;
4. Government mandates;
5. Market positioning; and
6. Business or project execution efficiency opportunities.

3.2 Developing A BIM Vision

Once a decision to adopt BIM has been made by the organization, it is critical to develop a vision for BIM implementation across the organisation.

The project manager can help develop a succinct and well-articulated vision by interacting with the business leadership team of the organisation. The vision must establish and communicate that BIM implementation is akin to a business transformation process that needs to be crafted carefully taking into consideration various aspects of the anticipated changes.

It is, therefore, essential to document in the visioning process the clear organisation-wide objectives of the BIM implementation; principal elements of how BIM has or is inducing transformation in the organisation; and how this evolution will take place over short to medium-term planning for the organisation. Essentially the project manager can help develop a strategy that conforms to the specific needs and business objectives of the organisation.

While keeping in mind that the project orientation of the organisation is crucial, the organisation-wide BIM vision and strategy needs to be distinctly different from the project-level BIM strategy. However, once this higher order vision is established, realistic BIM objectives at the company level can be translated appropriately into specific project-based BIM objectives.

3.3 Organisational Leadership and BIM Leadership

It takes leadership to translate the BIM vision into actionable strategies for the organisation. Identifying leadership at the right level is important for organisation-wide BIM implementation. It is always a challenge for the project manager to decide whether a push from top-management or project team level leadership will lead to the best BIM-related organisational transformation. It seems breakthrough transformations can only be achieved by blending the two approaches. The purely top-down approach of ‘let’s do BIM’ does not work as there may be limited buy-in from the project teams. Similarly, a bottom-up approach may not lead to best results as the influence of mid-tier team members on organisational issues may be limited. Finding a right balance of this leadership and creating congruency between organisational leadership and BIM leadership is essential.

This is where the role of the project manager becomes important at a strategic level.

3.4 Organisational Implementation Framework

Organisational level policies, processes, standards and goals can be set up by the project manager and the BIM manager alongside a budget that allows successful implementation of BIM at the organisation level. An organisation-level BIM implementation framework can be developed by the project manager to assist companies in their BIM implementation journey.

Information about the broad contours of the implementation framework is available in published literature and comprise of two main dimensions: (1) BIM Maturity Level Definitions; and (2) High-level Implementation Areas (Autodesk, 2012).

Table 7 shows the high-level implementation framework that project managers can use to guide the organisation in BIM implementation. As the organisation transforms from top to bottom on the BIM Maturity Levels, various strategies from the identified implementation areas are used to guide this transformation. Broadly these strategies straddle the people, process and technology areas of the implementation process.

Table 7: Organisation Level BIM Implementation Framework

BIM Maturity	Implementation Areas			
	Policies and Strategies	Organisational Change Management	Standards and Processes	Integrated BIM Technology
Governance	<ul style="list-style-type: none"> BIM Vision BIM Steering Committee BIM Contracts and Legal Policies 	<ul style="list-style-type: none"> BIM Training and Education BIM Roles and Responsibilities BIM Awareness and Communication Plan 	<ul style="list-style-type: none"> BIM Execution Plan 	
Model-Centric Workflows	<ul style="list-style-type: none"> Complete Lifecycle Asset Management 		<ul style="list-style-type: none"> Modelling and Project Deliverables Standards Quality Data 	<ul style="list-style-type: none"> Integrated and Multi-Disciplinary Geometric and Data Analysis
Collaboration and Data Management	<ul style="list-style-type: none"> Global Workflow Strategies 	<ul style="list-style-type: none"> Business Process Improvement 	<ul style="list-style-type: none"> Multi-site Collaboration Project Common Data Environment 	<ul style="list-style-type: none"> Project Auditing and Quality Control Standard Collaboration Processes
Integrated Analysis	<ul style="list-style-type: none"> Risk Mitigation and Claims Management Project Cost and Schedule Control 	<ul style="list-style-type: none"> Project Team Performance Measures 	<ul style="list-style-type: none"> Program-Wide Analysis and Master Planning 	<ul style="list-style-type: none"> Visualization Simulation and More Complex Analysis [4D, 5D and beyond]

Figure 11: Organisation Level BIM Implementation Framework

Skill Set	Technical	1	An individual's functional competence and expertise to use native BIM functions	Individual
	Social	2	An individual's leadership ability: To communicate within the team and motivate people to use BIM	
	Technical	3	An organization's core technical competencies: A company must know how to utilize native BIM functions and develop BIM capabilities	Organizational
	Social	4	An organization's BIM capabilities enable the organization to turn its technical know-how into desired lean and green outcomes	

Source: Adapted from Ulrich and Smallwood, 2004

3.5 Developing Organisational Capabilities

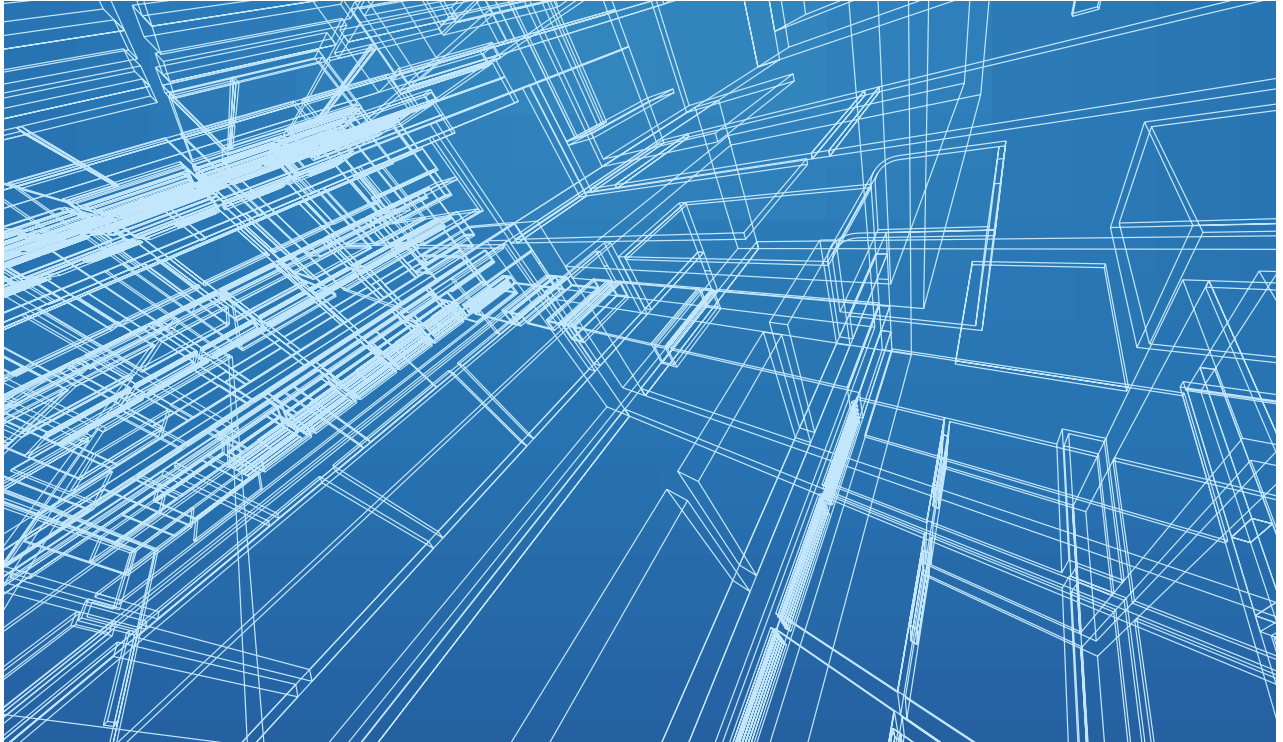
The project manager can help an organisation understand its BIM capabilities and maturity levels and chart out the resultant BIM journey for the organisation. Designing a training and capacity development framework that includes knowledge management for BIM can also be considered as an important aspect of a project manager's role.

According to Ulrich & Smallwood (2004), organisational capabilities are key intangible assets and emerge when a company delivers on the combined competencies and abilities of its individuals. This has been explained with the help of an organisational capabilities matrix where the individual and organisational levels of analysis are compared along with the technical and social skill set as shown in

Figure 11 (Ahuja, Sawhney and Arif, 2016). In the figure, the individual-technical layer (1) represents an individual's technical expertise for using various BIM functions. The individual – social layer (2) refers to an individual's leadership ability to communicate with and motivate people to use BIM functions. The organisational-technical layer (3) comprises of an organisation's core technical competencies, emphasising the necessity of an organisation knowing how to use their technical expertise and how to manage BIM implementation. The organisational social layer (4) represents an organisation's culture and personality which enables the organisation to turn its technical know-how with BIM into desired outcomes.

The project manager can utilize the framework described above to develop a competency based learning and development program for the organization. The knowledge management plan can also be created along the same lines.

4.0 Future of BIM and Project Management



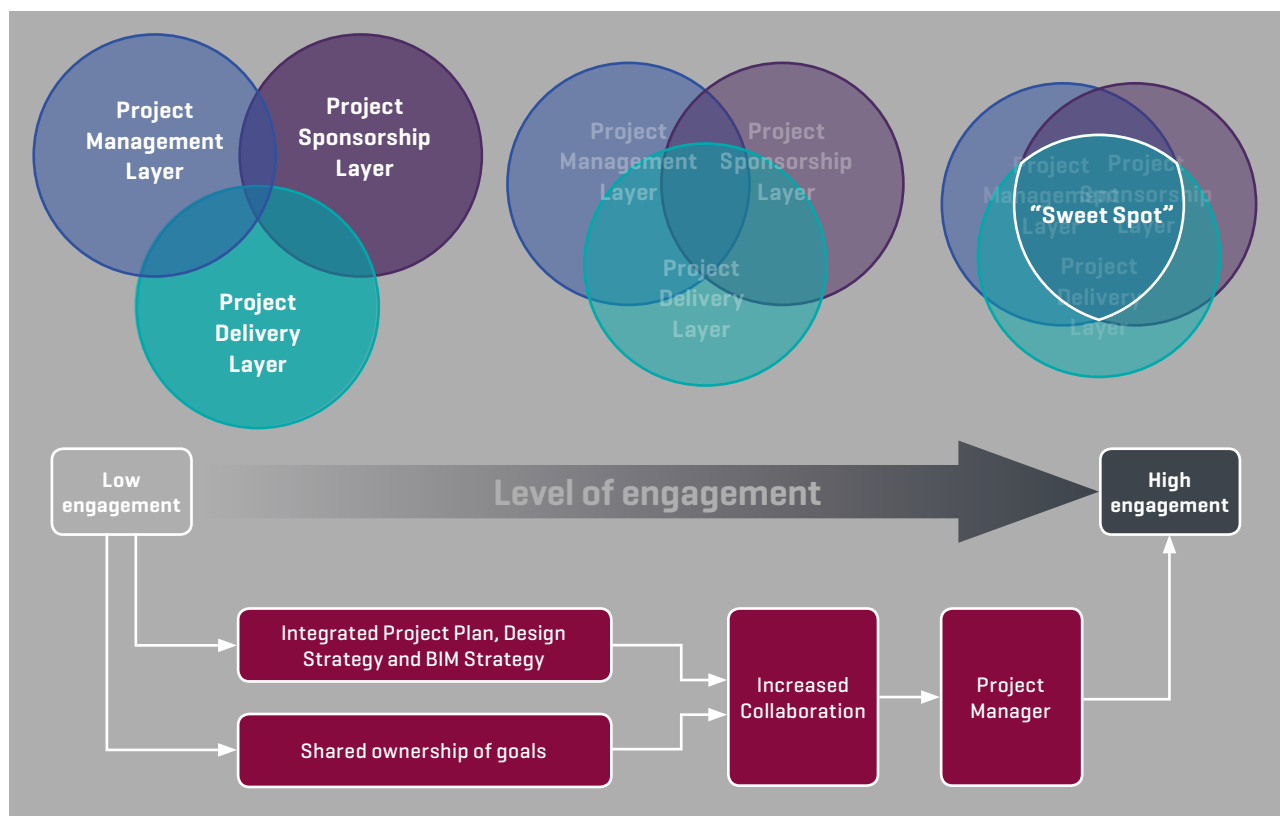
The future roadmap of BIM for project managers addresses the following three important areas:

- 1. Project managers must play a more proactive role in BIM implementation at both the project level and at the organisation level.** This will drive holistic BIM implementation and help in attaining project-level and organisation-level goals set for BIM implementation especially in downstream processes that follow the detailed design and engineering stages.
- 2. Project managers need to understand the ‘big picture’ for the changes induced by BIM that are happening in the built environment sector.** This will help individuals and organisations better understand emerging technologies and paradigms on the horizon and have the potential to disrupt the “business-as-usual” posturing in the industry. Project managers on the basis of this understanding can provide strategic advice to the organisations they work with or represent.
- 3. Project managers need to understand the new skills and competencies that may be required to fulfil their roles as the use of BIM becomes more pervasive in the industry.** This will have a direct impact on the educational and training needs of the industry.

4.1 Broader Role of Project Managers

Currently, project managers play a limited role in the meaningful implementation and use of BIM in the project delivery process. This may be due to the current over-emphasis on the use of BIM as a design tool and a passive role played by a majority of project managers when it comes to BIM. The situation is bound to change as the use of BIM becomes more pervasive. The ultimate goal of this holistic participation of project managers in the BIM process can be explained as the development of a “sweet spot” between the project management layer, the project sponsorship layer and the project delivery layer (Spehar, 2016). This was originally conceived as a sweet spot between project management, design management, and BIM management. Figure 12 illustrates this idea.

In a non-BIM environment there is a relatively low-level of engagement among the project team members leading to lower level of collaboration and synergies between the project management layer, the project sponsorship layer and the project delivery layer. As the project manager starts driving BIM for better collaboration, shared ownership of project goals, and synergies between the project plan, design strategy and BIM strategy, the level of engagement increases and a “sweet spot” develops.

Figure 12: Broader Role of Project Managers in BIM Implementation

This essentially means project managers are able to drive better operational efficiencies on the project and obtain superior gains from BIM implementation.

4.2 Emerging Technologies and Paradigms

The built environment sector is striving to be a highly efficient, quality-centred, socially responsible and buoyant industry capable of successfully delivering the requirements of current and future generations. Using BIM as a tool, project managers can play a strategic role in this transformation, but it would be naïve to assume that BIM alone (if at all) can make such sweeping changes.

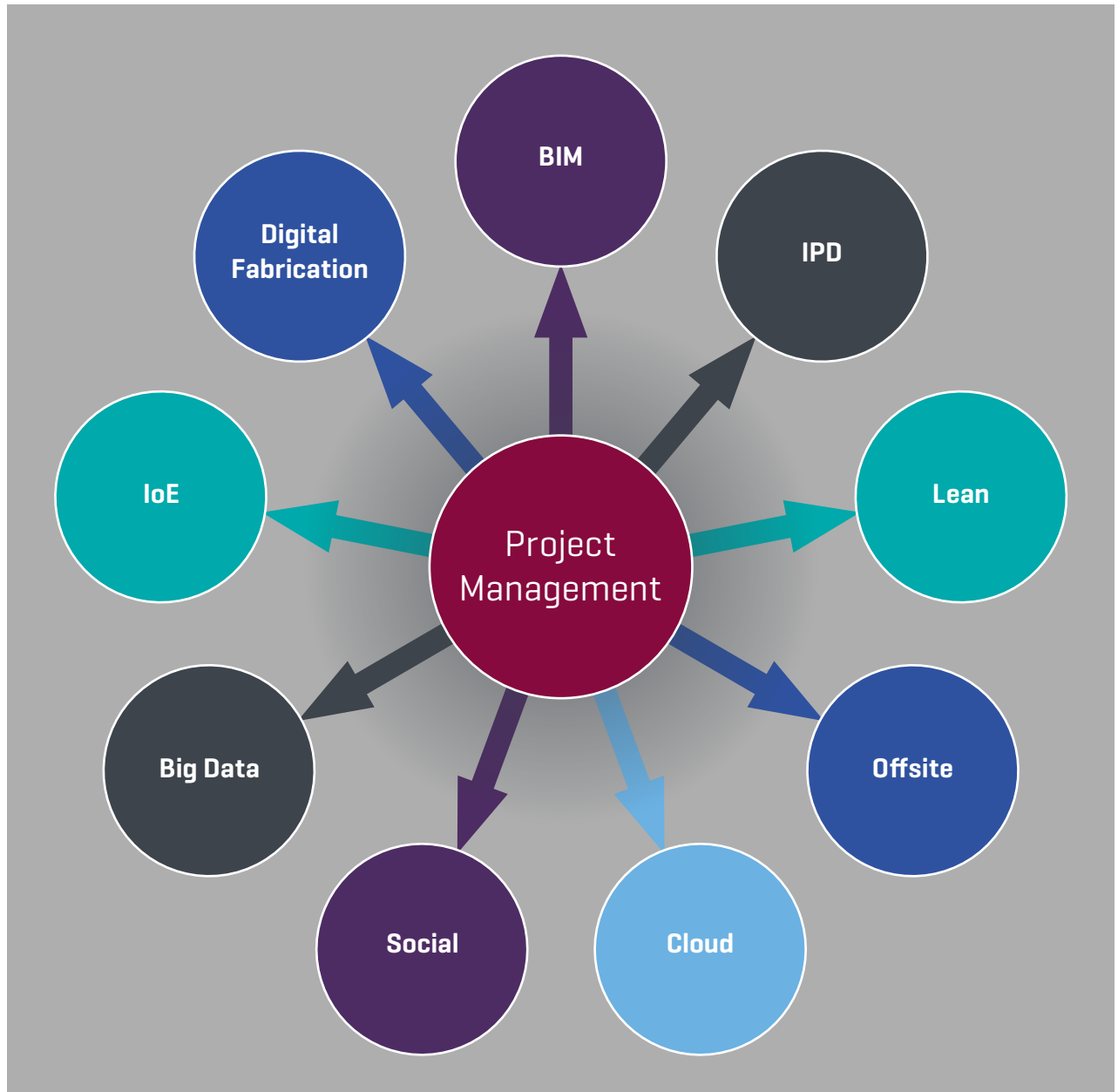
But it is clear that BIM, along with other complementary technologies and paradigms, can provide the necessary impetus. Therefore it is key that the project manager has a clear understanding of these technologies and paradigms and how they interlink to the project management domain.

Figure 13 shows a set of emerging technologies and paradigms being highlighted by the built environment sector. Many researchers and industry professionals have pointed out significant synergies and overlaps between these (Sacks et al., 2009; Dave et al., 2013;

Mahalingam, Yadav and Varaprasad, 2015; Tauriainen et al., 2016; Enache-Pommer et al., 2017). For example, offsite technologies have been shown to use BIM as a driver to accomplish project management success and sustainability goals. Similarly, a significant inter-linkage between lean, green and BIM paradigms has been documented on built environment projects (Ahuja, Sawhney and Arif, 2014, 2016). Data technologies in conjunction with BIM can be tapped to enhance the design, construction, operation and maintenance of our built environment, thereby having significant importance for the project management community.

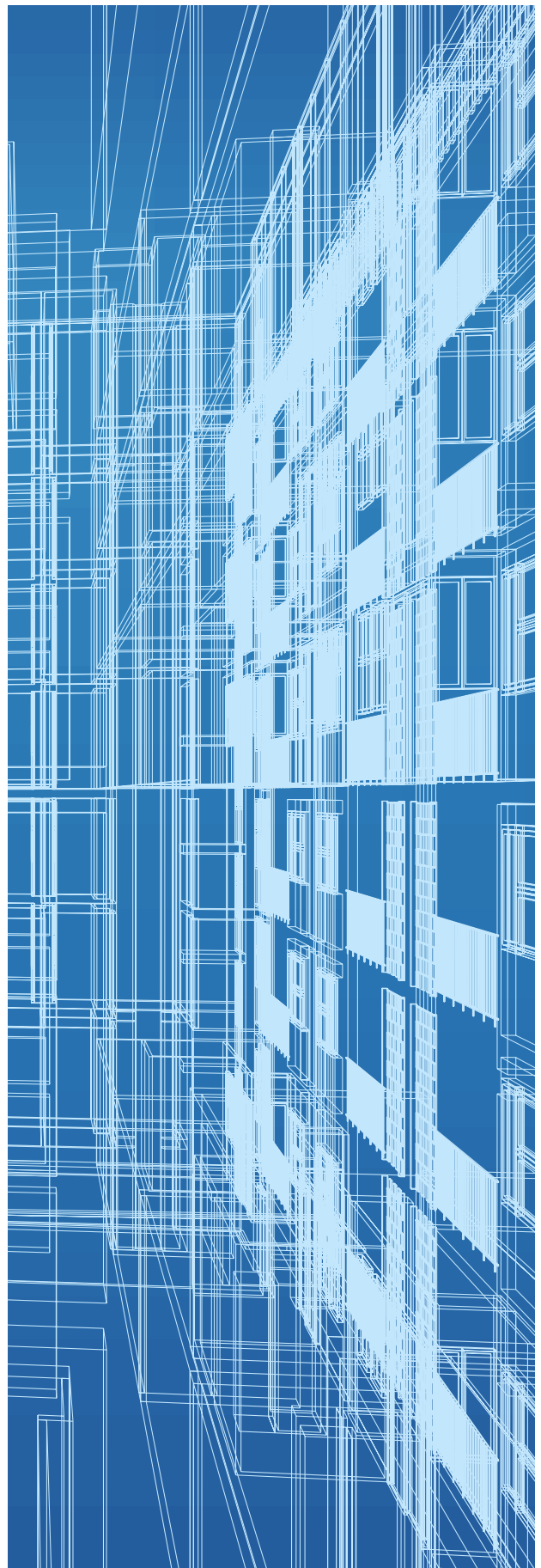
As project managers take on advisory roles at the organisation level, there is a need for them to assist their organisations in scanning emerging technologies and paradigms that will most likely have a significant impact on the sector. Very often organizations end up taking the 'adopt one-at-a-time approach' when it comes to the adoption of emerging technologies and paradigms (Cone, 2009). This is where project managers can play a strategic role in ensuring that organizations take a more holistic view of the BIM transformation process and keep in mind the interlinked emerging technologies and paradigms.

Figure 13: Emerging Technologies and Paradigms in the Built Environment Sector



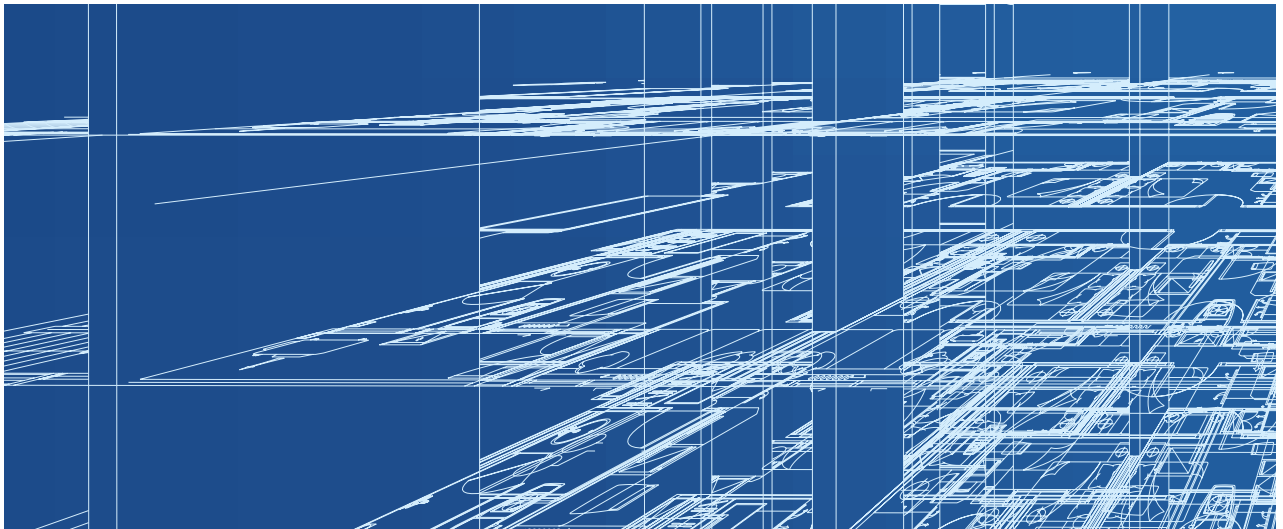
5.0 Conclusions and Recommendations

Project managers will play a central role in the usage of BIM on built environment sector projects. They will guide organizations at a strategic level on issues pertaining to organizational transformation mandated by BIM. As BIM becomes a vehicle for exploring the adoption of other emerging technologies and paradigms, project managers will have to assist organizations and project teams in this journey. This requires project management as a discipline to consider both the internal and external implications of BIM. Internally there is a need for project managers to re-evaluate their role, responsibilities, and project management practices both at the project level and at the organizational level. Externally they must take on their role as a 'project integrator' facilitating the use of BIM across the entire lifecycle of projects. This is crucial as data and information is becoming abundant in the model-centric delivery processes of the built environment sector. A project manager can harness the power of this data and information in improving the operational efficiency of their project management functions along with those functions related to BIM implementation. Through its prowess in visual communication, information database management and compatibility with analysis and process workflows, BIM is finding its way to being useful in the entire project life cycle starting from design through to construction and into operations. Project managers must take on the increasingly important role of advising organisations and projects teams on how best to use project management principles in deploying BIM and associated emerging technologies and paradigms.



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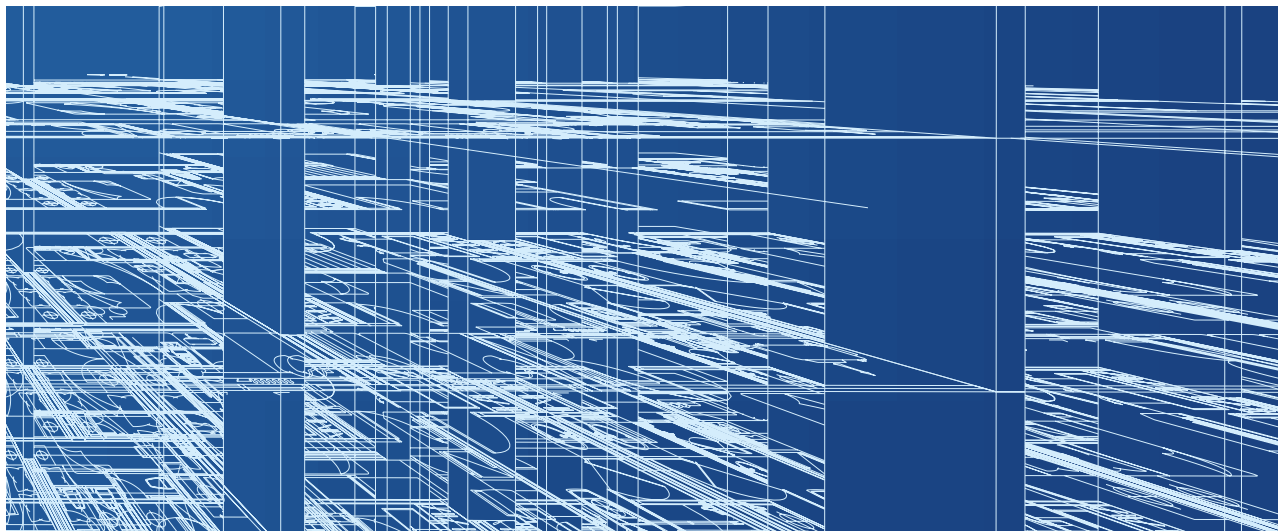
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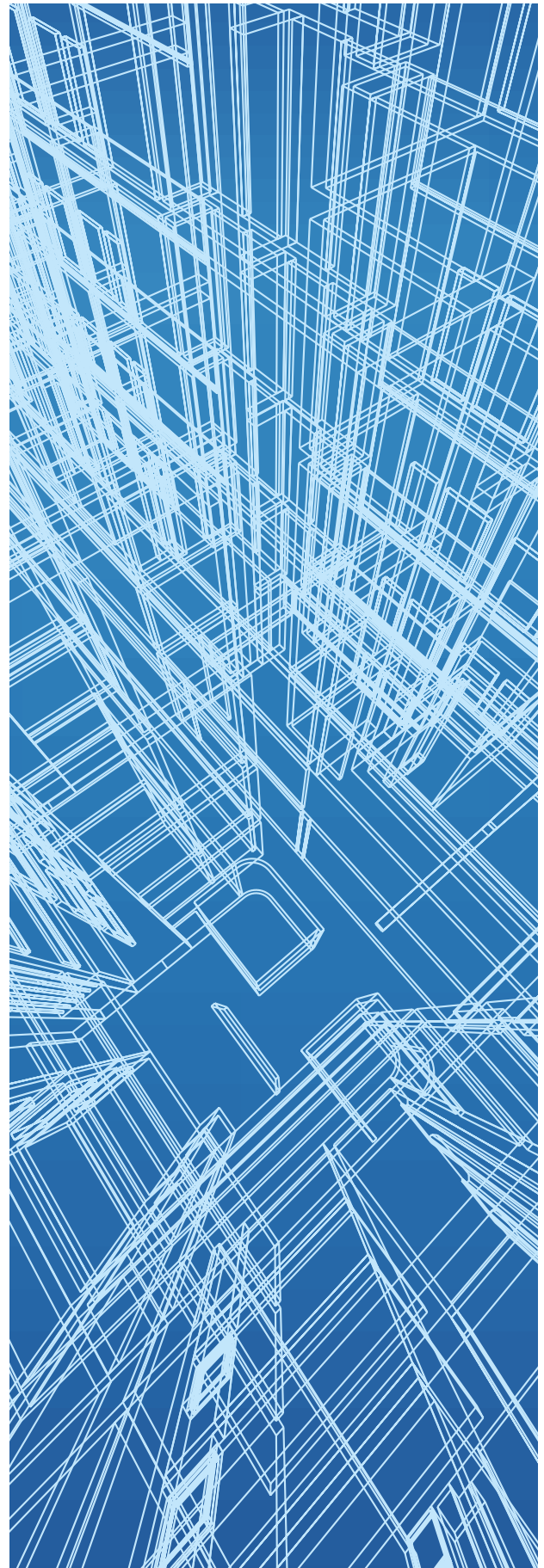
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