

Principles of Implementing 4d Bim for Time Management in Major Project Delivery

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ABSTRACT : Time overrun remains one of the most persistent problems in major construction projects, and more than half of UK projects still exceed their agreed programmes. Four-dimensional building information modelling (4D BIM), which links the construction schedule to a 3D model, has been promoted as a way to make planning more reliable, yet its use in practice remains uneven. This paper examines the principles of implementing 4D BIM for time management in major project delivery. It follows a qualitative approach that combines a structured review of literature, industry guidance and policy with a comparative analysis of published surveys and interview studies of 4D BIM use, mainly from the UK and Sweden. The factors that shape adoption are grouped into technical, procedural and people-related categories, and a practical implementation sequence is set out, from reliable data capture and collaborative planning to the integration of model and programme. Applications across the construction phase are then mapped, covering tender planning, construction method planning, programme communication, design interrogation, resource and workspace planning, safety and logistics. The comparative analysis shows a consistent pattern: awareness of 4D BIM is high, but routine use lags behind, and the technology is valued more for communicating and checking programmes than for creating them. The main barriers are a shortage of 4D skills, limited client demand, poor interoperability between authoring and scheduling tools, mismatched levels of development and traditional procurement. On this basis the paper proposes three practical approaches, clarity, collaboration and adaptation, supported by SMART 4D objectives, early involvement of the 4D team, staged training and a ring-fenced implementation budget. The main limitation is that the time savings are not quantified on live projects, which remains a subject for further research.

KEYWORDS: 4D BIM, time management, construction scheduling, project delivery, BIM adoption, UK construction industry

I. INTRODUCTION

Delivering major construction projects on time is a long-standing challenge. Time, cost and quality remain the core measures of project success (Baccarini, 1999), but time is often the first to slip. Studies of delay repeatedly point to weak planning and poor information flow, rather than unforeseeable events, as the main causes of poor time performance (González et al., 2014; Olawale & Sun, 2010). In the UK, more than half of construction projects still exceed their agreed schedules (Gledson & Greenwood, 2016).

Conventional planning tools such as bar charts and the critical path method describe the sequence and duration of activities, but they say nothing about where those activities take place. The programme is usually prepared separately from the design, which makes it hard for stakeholders to picture how the work will unfold on site and easy for spatial conflicts to go unnoticed until construction (Koo & Fischer, 2000). 4D BIM addresses this gap by linking each activity in the schedule to the model elements it produces, so that the construction sequence can be simulated, checked and communicated before work begins (Eastman et al., 2011; Hartmann et al., 2008).

Despite these advantages and strong policy support for BIM in the UK, the uptake of 4D BIM has been slower than

expected. Practitioners report a shortage of skills, little client demand, software that does not exchange data well, and contracts that do not reward early collaboration (Kassem et al., 2012; Gledson & Greenwood, 2017). There is also little clear guidance on how organisations should introduce 4D BIM so that it actually improves time management, rather than producing simulations that are used once at bid stage and then set aside. This paper responds to that gap. Its aim is to examine the principles of implementing 4D BIM for time management in major project delivery. The objectives are to:

- review the concept of 4D BIM and its role in time management;
- identify the key factors, procedures and applications that support effective implementation;
- compare published survey evidence on how 4D BIM is used in practice; and
- propose practical approaches for integrating 4D BIM into project time management.

1. Research Approach

The study takes a qualitative approach in two stages. First, a structured review of journal papers, conference proceedings, industry guidance and UK government reports was carried out to establish the principles, applications and barriers of 4D BIM. Second, published surveys and interview studies of 4D BIM use, drawn mainly from the UK and Sweden, were

compared to test whether the themes from the review are reflected in practice. The results of both stages were combined to develop the approaches proposed in section 4.4. The literature is reviewed in section 2, the factors affecting adoption are set out in section 3, the comparative analysis is presented in section 4, and conclusions are drawn in section 5.

II. LITERATURE REVIEW

1. Time Management In Major Project Delivery

Time management in construction covers the planning, sequencing, scheduling and control of activities so that milestones are met within the agreed period. In major projects this is complicated by the number of interfaces between trades, the scale of resources involved and the range of stakeholders, each with their own priorities. Delay has knock-on effects: cost overruns, contractual penalties, disputes and damaged working relationships (Olawale & Sun, 2010). González et al. (2014) found that poor time performance stemmed mainly from inadequate planning rather than from unexpected events, which suggests that better planning tools can make a real difference.

Five principles of time management in major projects can be drawn from the literature: strategic planning, in which the work is broken into manageable activities with realistic durations; resource allocation that avoids bottlenecks; logical sequencing and prioritisation of tasks; proactive risk management; and open communication among stakeholders. Each depends on the project team sharing an accurate and current picture of how the work will proceed, and this is precisely where conventional 2D planning struggles (Gledson & Greenwood, 2016).

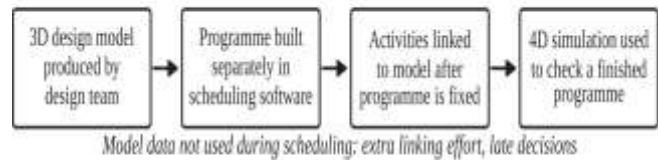
2. From Bim To 4d Bim

BIM is best understood not as a software product but as a process that brings people, information and technology together around a shared digital model (Azhar, 2011; Eastman et al., 2011). Model elements carry a level of development (LoD), from LoD 100 to LoD 500, which signals how far their geometry and data can be relied on. Adding time to the 3D model produces 4D BIM, in which each scheduled activity is linked to the elements it constructs, removes or temporarily occupies. The result is a simulation of the construction sequence that planners and other stakeholders can review together (Koo & Fischer, 2000).

Early studies showed that 4D models help teams identify spatial and temporal conflicts, check constructability and explain the programme to people who do not read Gantt charts easily (Hartmann et al., 2008; Mahalingam et al., 2010). A recurring criticism, however, concerns the way 4D BIM is used. In the typical workflow the schedule is produced first in dedicated scheduling software and only

afterwards linked to the model, so BIM serves to check a finished programme rather than to inform it (Figure 1). Because model data are not used during scheduling, linking the two adds time and cost and delays decisions. An integrated workflow, in which zones, quantities and sequencing logic are drawn from the model while the programme is being built, offers more value but requires more mature processes (Mazars & Francis, 2020).

(a) Conventional workflow



(b) Integrated workflow

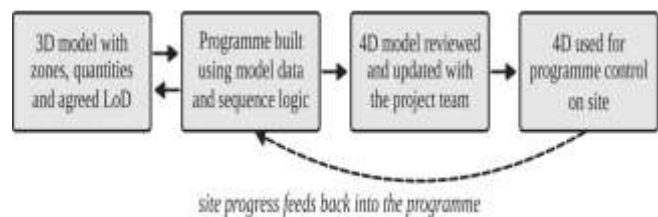


Figure 1: Conventional and integrated 4D BIM workflows.

3. The Uk Context

UK construction policy has pressed for better collaboration since the Latham (1994) and Egan (1998) reports. The Government Construction Strategy 2011–2015 introduced the Level 2 BIM requirement for central government projects, and its successor for 2016–2020 continued to treat BIM as central to more efficient delivery (HM Government, 2016). The Construction 2025 strategy went further by targeting a 50% reduction in overall delivery time, with 4D BIM seen as one of the means of achieving faster and more predictable delivery (Gledson & Greenwood, 2017). Yet policy documents say little about how the time-related benefits of 4D BIM should be realised, and surveys of UK practitioners continue to report a gap between awareness and routine use (Gledson & Greenwood, 2016, 2017). Much of the existing research also concentrates on individual applications or software tools rather than on the principles that allow 4D BIM to improve time management across a project. This paper focuses on those principles.

4. Key Factors Affecting Bim Adoption For Effective Time Management

1. Implementation Factors And 4d Maturity

Successful use of 4D BIM depends on three groups of factors. The first is technical: the availability, cost and

interoperability of software and hardware. The second is procedural: how 4D modelling is built into existing planning and information management processes. The third concerns people: the knowledge, skills and willingness of individuals and organisations to work in a new way (BIM+, 2021; Kassem et al., 2012). Many organisations have not yet decided where 4D fits in their business, and those that use it often cannot say how mature their practice is, which makes it hard to set targets for improvement.

A 4D maturity matrix offers a practical starting point. It assesses technical, procedural and personal measures across

Table 1: Five levels of 4D BIM maturity (developed from BIM+, 2021).

Level	Technical	Procedural	Personal
Ad hoc	Basic 3D model linked to a high-level programme; permanent works only	No defined process; 4D produced for a single purpose such as a bid	One person creates and presents the model
Defined	Model divided into zones that match programme activities	Documented workflow for building and updating the model	Planner and BIM coordinator share responsibility
Managed	Temporary works, logistics and plant included	4D reviewed against the programme at set points	Site teams review and comment on the model
Integrated	Model data such as zones and quantities used while the programme is created	4D embedded in planning, progress reporting and change control	Multi-disciplinary, multi-author working including subcontractors
Optimised	Model updated from site data to reflect actual progress	Continuous improvement from lessons learned	Whole supply chain creates and uses the model

2. Implementation Procedure

Three conditions form the basis of effective implementation. The first is reliable information: the 3D model is only as good as the data behind it, so drawings, specifications, survey data and records of existing structures must be accurate and current. The second is collaborative planning: architects, engineers, contractors and key subcontractors should agree the sequence, key activities and milestones together, so that the 4D model reflects a shared view of how the project will be built. The third is integration with the scheduling software, so that changes to the programme appear in the model and their effect on the timeline can be seen straight away (Eastman et al., 2011).

At a practical level, the 4D model can be developed in four steps (Figure 2). A 3D model is first created or, for existing buildings, converted from 2D drawings or laser-scan data. The programme is then prepared in scheduling software such as Primavera P6 or MS Project and filtered to remove activities that do not relate to model elements, such as design and procurement milestones. Next, the model is

divided into levels and zones that match the programme, typically through IFC export. Finally, model and programme are linked in a 4D tool such as Navisworks or Synchro:

five levels, from ad hoc to optimised (Table 1). At the lowest level the 4D model may show only the permanent works, prepared by one person and presented to the team as a finished output. At the highest level the model is updated continually, reflects actual site conditions and is reviewed by a multi-author team that includes site managers, subcontractors and third parties. Most organisations sit towards the lower end. The value of the matrix is that it lets a team see where it stands and set small, achievable steps towards better practice.

selection sets are created and linked to activities, and the simulation settings are aligned with the programme dates. For refurbishment and demolition work, activities affecting the existing structure must be identified separately so that the simulation can distinguish what is retained, removed and built.

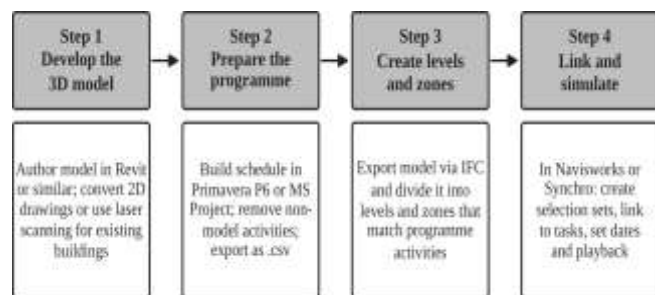


Figure 2: Four-step workflow for developing a 4D BIM model.

3. Applications Across The Construction Phase

Although practitioners broadly agree on the potential of 4D BIM, BIM in general is still used more in the design and pre-construction stages than during construction itself (Eadie et

al., 2013). The applications of 4D BIM fall into construction planning and site planning, and those most relevant to time management are summarised below.

- Tender stage: simulations help contractors explain their proposed approach, test whether the programme is realistic and identify risks before pricing.
- Construction method planning: alternative sequences can be tested virtually to find the one that shortens duration and makes best use of resources.
- Programme communication: a visual sequence is easier for clients and site teams to follow than a Gantt chart, which reduces misunderstandings (Hartmann et al., 2008).
- Design interrogation: constructability problems and spatial-temporal clashes become visible before work starts (Mahalingam et al., 2010).
- Resource and workspace planning: the model shows when and where labour, plant and storage are needed, which helps to avoid congestion and idle time (Chavada et al., 2012).
- Safety and logistics planning: hazards can be linked to particular locations and periods, and decisions on site access and deliveries can be tested (Tran et al., 2021).
- Progress monitoring and short-term planning: comparing the model with site data highlights deviations from the planned sequence (Braun et al., 2015), and 4D has been combined with constraint-based, look-ahead planning (Sriprasert & Dawood, 2003).

5. Barriers To Effective Use

The barriers to 4D BIM are partly technical and partly organisational, and the organisational ones appear harder to overcome (Table 2). On the technical side, models from different disciplines are produced by different parties, at different times and at different levels of development. When the model is less developed than the work breakdown the programme needs, it has to be split and regrouped before it can be linked, which is labour-intensive (Boton et al., 2015). Weak interoperability between authoring tools, 4D tools and legacy scheduling programmes adds to the effort and helps to explain why 4D BIM is often limited to smaller projects with fewer activities (Mazars & Francis, 2020). Automation of model breakdown and schedule linking is still underdeveloped (Farnood Ahmadi & Arashpour, 2020).

The non-technical barriers include a lack of standards and execution plans, low client demand, high software and training costs, a shortage of 4D expertise, resistance to changing established planning practice, and traditional procurement routes that discourage early collaboration (Kassem et al., 2012). Smaller firms feel these obstacles more sharply because they have fewer resources to invest (Migilinskas et al., 2013). Decisions on model scope and

level of detail also matter: a model built for a bid needs far less detail than one intended to control the whole construction period, and the right balance depends on its purpose.

Table 2: Main barriers to 4D BIM adoption.

Category	Barrier	Sources
Technical	Poor interoperability between authoring, 4D and scheduling tools	Mazars & Francis (2020)
Technical	Mismatched levels of development across disciplines and programme	Boton et al. (2015)
Technical	Limited automation of model breakdown and schedule linking	Farnood Ahmadi & Arashpour (2020)
Process	Lack of standards, guidance and execution plans; traditional procurement	Kassem et al. (2012)
People	Shortage of 4D skills; resistance to change; responsibility confined to the planner and BIM coordinator	Kassem et al. (2012); Crowther & Ajayi (2021)
Economic and client	Software and training costs; low client demand; fewer resources in small firms	Kassem et al. (2012); Migilinskas et al. (2013)

6 Overview Of 4d Bim Impact On Time Management

1. Comparative Analysis Of Published Studies

To test whether the themes from the review hold in practice, published empirical studies of 4D BIM use were compared. Studies were included if they reported primary survey, interview or case study data from practitioners and addressed the use, benefits or barriers of 4D BIM. The UK studies were complemented by a Swedish study, which offers a second national context in which BIM is well established. Table 3 summarises the studies and their

main findings. Because they differ in sample, timing and question design, the comparison concentrates on recurring themes rather than on combining figures.

Table 3: Published empirical studies compared

Study	Context and data	Main findings relevant to time management
Mahalingam et al. (2010)	India; case studies of 4D CAD use	Benefits in communicating plans, identifying conflicts and tracking progress; wider use needs integration with existing planning procedures
Kassem et al. (2012)	UK; survey of practitioners	Software and training costs, a shortage of 4D expertise and limited client demand among the main barriers
Eadie et al. (2013)	UK; survey across the project lifecycle	BIM used more in design and pre-construction than in construction and operation; clients seen as the main beneficiaries
Gledson & Greenwood (2016)	UK; survey of 136 practitioners	High awareness; 4D used for work winning, method planning and validating processes; valued for handling and communicating information more than for creating or controlling timescales
Gledson & Greenwood (2017)	UK; survey of 97 planning practitioners	Adoption rising over time, with a lag between awareness and first use; system compatibility and safe trialling encourage adoption
Sedigi (2018)	Sweden; survey of clients and contractors	Awareness strong but use limited; clients and contractors see benefits and barriers similarly; lack of 4D experience and traditional delivery methods are key barriers
Crowther & Ajayi (2021)	UK; 6 interviews and 50 questionnaires	Eight ways 4D BIM supports performance, grouped under reliability, monitoring and diagnosis; limited training and narrow responsibility as challenges

2. Impact On Time Management

Taken together, the studies show that 4D BIM supports time management in three main ways. The first is planning reliability: visualising the sequence improves planning efficiency and allows planners to test whether a programme is realistic before it is fixed. The second is monitoring: by comparing planned and actual progress against the same model, teams can spot deviations earlier and give clearer direction on site. The third is the diagnosis of risk: 4D models allow risks to be considered more thoroughly and in good time, and help prevent problems from recurring (Crowther & Ajayi, 2021). The studies also agree on what 4D BIM is valued for most: explaining the construction design, visualising the flow of work and checking programmes through simulation. Practitioners regard it as better than conventional planning at handling and communicating information, but not yet as a better tool for creating the programme itself, which still relies on experienced planners (Gledson & Greenwood, 2016). This distinction matters, because poor information handling is one of the main reasons that programmes prepared with 2D methods prove unreliable. The principal contribution of 4D BIM to time management is therefore to improve the shared understanding on which good planning decisions depend.

3. The Gap Between Awareness And Use

A consistent finding across the UK and Swedish studies is that awareness of 4D BIM is high while routine use remains limited (Gledson & Greenwood, 2017; Sedigi, 2018). Gledson and Greenwood (2017) describe a time lag between first hearing of 4D BIM and first using it, which is typical of

this kind of innovation. Where 4D BIM is used, it tends to be applied at tender stage and in early method planning rather than throughout construction (Eadie et al., 2013; Gledson & Greenwood, 2016). Short-term, look-ahead planning, where 4D could support week-to-week control, remains among the least developed uses. The reasons given for this gap match the barriers identified in section 3.4: a shortage of 4D experience in the market and within organisations, low client demand, the cost of software and training, and the persistence of traditional delivery methods (Kassem et al., 2012; Sedigi, 2018). Clients and contractors tend to see the benefits and barriers in much the same way, which suggests that the obstacle is not disagreement about value but a lack of mechanisms to realise it. Responsibility for the 4D model also tends to rest with the planner and BIM coordinator alone, which limits its influence on site decisions (Crowther & Ajayi, 2021). Government policy and client requirements emerge as the strongest drivers of adoption.

4. Proposed Practical Approaches

Drawing on the review and the comparative analysis, three approaches are proposed to make 4D BIM a working part of project time management: clarity, collaboration and adaptation (Figure 3).

Clarity. 4D BIM objectives should be set at the outset in SMART terms (specific, measurable, achievable, relevant and time-bound) and tied directly to the project's time objectives, for example by defining the stages at which the 4D model will be used to validate the programme and the level of detail needed at each. The organisation's current

position on the maturity matrix (Table 1) should be assessed so that the targets are realistic.

Collaboration. Clients, designers, contractors, key subcontractors and the 4D team should be involved from the start, so that the sequence reflects a shared understanding of scope and constraints. Responsibility for reviewing the model should extend beyond the planner to site managers and trade contractors, and procurement routes that reward early contractor involvement make this easier to achieve.

Adaptation. The model should be updated regularly with site progress so that it remains a reliable basis for decisions, and lessons learned at completion should feed into the next project. Skills gaps can be closed through staged training, from introductory awareness to advanced practical use, supported by internal knowledge-sharing sessions in which experienced users present completed projects, and by feedback that shows whether the training is working. Setting aside part of the project budget for 4D implementation, and training existing staff rather than relying only on new recruitment, helps to manage the initial cost. Earlier detection of spatial and temporal clashes then reduces rework and recovers part of that investment.

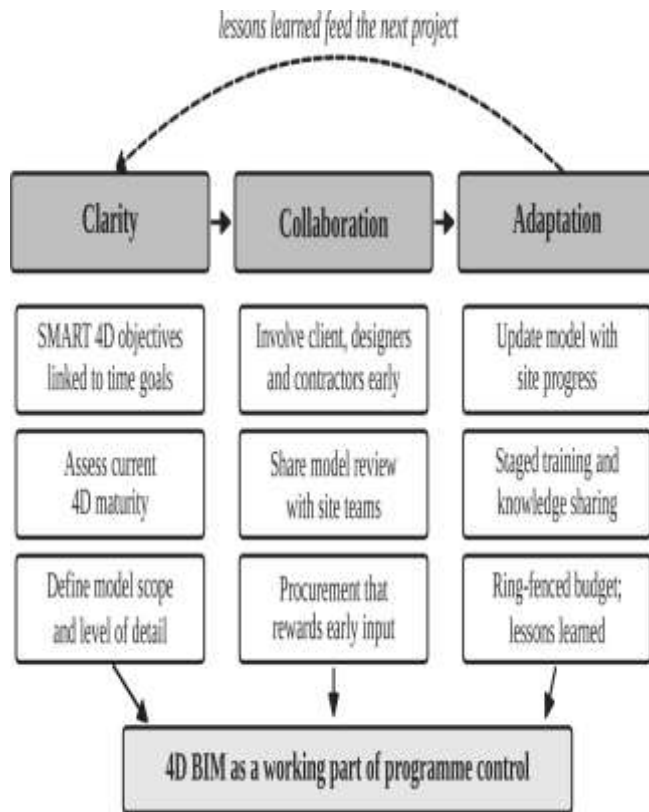


Figure 3: Proposed approaches for integrating 4D BIM into project time management.

III. CONCLUSION

This paper examined the principles of implementing 4D BIM for time management in major project delivery. Linking the construction programme to the 3D model allows teams to test, communicate and monitor the sequence of work in ways that conventional planning tools cannot. The literature and the published survey evidence agree that 4D BIM improves planning reliability, supports the monitoring of progress and helps teams consider risk more thoroughly and in good time.

The comparative analysis also shows that these benefits are not yet widely realised. Awareness of 4D BIM is high in both the UK and Sweden, but routine use lags behind, and the technology is applied mostly at tender and early planning stages rather than throughout construction. It is valued more as a means of communicating and checking programmes than as a tool for creating them. The main obstacles are a shortage of 4D skills in the market and within organisations, limited client demand, the cost of software and training, poor interoperability, mismatched

levels of development between model and programme, and traditional procurement. These are organisational problems as much as technical ones.

To address them, three practical approaches are proposed. Clarity means setting SMART 4D objectives tied to the project's time goals and assessing current maturity. Collaboration means involving all key parties, including site teams and subcontractors, from the outset and sharing responsibility for the model. Adaptation means keeping the model current, learning from each project and building skills through staged training supported by a ring-fenced budget. Together, these steps can help move 4D BIM from a presentation tool used at bid stage to a working part of programme control.

For practitioners, the findings suggest that the greatest gains will come from changes in process and people rather than from new software. For clients and policymakers, they point to the value of specifying how 4D BIM should be used, not simply that it should be used. The main limitation of the study is that it relies on published evidence and does not quantify the time savings of 4D BIM on live projects. Future research should measure these effects across different project types and test the proposed approaches in practice.

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