## Activity-based vs. Object-based Scheduling in Construction: A Phenomenological Study of the potential shift of Construction Scheduling Process

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###### Abstract

Construction activities scheduling can be seen as the backbone process of any construction project to ensure its successful delivery. A sound construction project schedule allows informed decisions, appropriate actions and improved management of actions. Construction planning is based on activity scheduling and many tools and applications have been developed to manage durations, resources and risks. However, this is time-consuming, error-prone and insufficiently coordinated because of the continual acquisition and updating of data needed to keep the plan relevant. To help this, 4D BIM technology is seen as revolutionary digital solution which can automate much of the effort as well as producing better output and to operate this in real time. This move to 4D BIM technologies for planning puts more emphasis on the objects in the 3D model and these become the drivers of the schedule. This study aims to unpack the difference between activity based and object-based emphasis in construction project planning so that the full advantages of 4D BIM technologies can be met. In-depth narratives from planners and 4D Modeller for one of the contractors in the UK are used to capture the potential complexities resulting from using object-based scheduling. These narratives highlight the gains and shortfalls of this scheduling process, while analytically comparing it to activity-based scheduling. Analysis suggests that the phenomenological shift in scheduling practice from using 4D BIM can have inappropriate outcomes. This has deep implications on both the future development of 4D BIM technologies and construction scheduling process.

**Keywords:** Construction, Scheduling, 4D BIM, Activity-based, Object-based,

* 1. **Introduction**

For many years, construction scheduling is continually gaining the attention by researchers and practitioners. This is due to the fact that construction projects are inherently complex, dynamic and involve many processes (Lee et al., 2006). With the advent of information technology, planning and scheduling within construction projects are still based on principles that were established since the 1950s, namely Critical Path Method (CPM) and Programme Evaluation and Review Techniques (PERT). Thus, with the existence of many programming computer applications such as Microsoft Project and Asta powerproject, they are still based on these principles (Ahuja and Thiruvengadam, 2004). However, with the increase of complexity of construction projects, and the need to communicate information in a more efficient manner, there was a need to begin shifting towards more reliable processes that can support handling vast amount of information, and inform decisions more effectively (Crotty, 2012). The introduction of 4D BIM has provided a competitive advantage in terms of having more robust approach towards informing scheduling of construction activities (Jupp, 2017). 4D BIM has been used to tackle many complex issues including clashes on site, logistics management and monitoring of construction progress. However, with the initiative of 4D BIM, other challenges have arisen including time and effort to create the simulations, hence recent applications began to simplify such complexities through scheduling directly off the 3D Models. This paper aims to explore the potential impact of this phenomenological shift, which would make the planners to perform object-based scheduling as oppose to activity-based (traditional CPM-based applications) scheduling. The nature of this distinction will be explored and its importance demonstrated through a phenomenological approach. The idea of phenomenology refers to the experience of planning and the importance of this will be presented particularly for improvement.

* 1. **Literature Review**

**2.1 Construction scheduling: an overview**

Improving the scheduling of construction activities has continually been an interest for many researchers and practitioners. Unlike other industries, every construction project is unique in nature, complexity and characteristics (Ahuja and Thiruvengadam, 2004). Planning and scheduling mainly compose of activity durations, resource allocation, monitoring and management. The estimation of activity durations has received great attention due to its complexity and the amount of time and effort it needs. Ben-Haim and Laufer (1998) presented a concept to improve reliability of project schedule through minimal information, incorporation of subjective information and its simplicity to use. Inevitably, resources-related considerations form one of the main pillars of construction scheduling. In fact, for many projects, resources are seen as one of the ‘constraints’ that drive scheduling of construction activities (Liu and Wang, 2012). Projects of that nature are called ‘resource constrained projects’ (Kastor and Sirakoulis, 2009).

In fact, and yet a widely adopted approach for planning and control in the construction industry is the use of techniques such as Critical Path Method (CPM), Programme Evaluation and Review Technique (PERT) and Earned Value Method (EVM). These techniques have many advantages (Harry, 2004), but they mainly utilise static approach, hence more dynamic approaches towards to scheduling are being used including simulations and generic algorithms (Fischer and Aalami, 1996). In fact, it was stated that current construction scheduling tools require vast translation of design information to activities, which require both time and effort. Nowadays, there exists an abundance CPM-based computer application to support more robust approach towards construction scheduling (Ahuja and Thiruvengadam, 2004). Simultaneously, simulation techniques are becoming more widely accepted to planning and analysis (Lu and AbouRizk, 2000). However, with the increasing complexity of construction projects, and more importantly the demand for more information (Crotty, 2012), there was a need to shift towards more reliable processes that can support the major task of planning and scheduling. It is argued that through leveraging the use of 4D BIM, potential improvements can be achieved in terms of communication, information flow and management of on-site activities (Jupp, 2017).

**2.2 BIM-based Scheduling**

Within the past decade, 4D BIM is increasingly being used to support construction planning, scheduling and control of production (Choi et al., 2014). Conceptually, the term ‘4D BIM’ refers to linking a schedule of activities to a 3D Model in order to produce a dynamic visual representation of construction activities (Gleeson and Greenwood, 2016). In fact, a number of terms is used to describe 4D BIM including 4D CAD, 4D Modelling, 4D Planning and Scheduling, and 4D Simulation (Buchmann-Slorup and Anderson, 2010; Jupp, 2017). According to Koo and Fischer (2000), generating 4D Model requires a 3D geometric model with building components, construction schedule/programme and a 4D environment that allows linking the 3D model with the construction schedule to create the 4D simulation. 4D BIM has benefited the construction industry in terms of enhancing coordination and visualisation of the schedule both for existing and new projects (Umar et al., 2014).

Research showed that there are a number of 4D BIM functionalities, which were used to capture many of the common issues faced on construction sites. The visualisation functionality was used to detect conflicts between workspaces (Chavada et al., 2012), analyse progress of simultaneous activities located in adjacent spaces (Moon et al., 2014) and analytically gain richer insights of construction progress and workspace logistics (Golparvar-Fard et al., 2009). The embedded functionality of collaboration in design and construction within 4D BIM is effectively utilised to coordinate different construction designs and schedules (Trebbe et al., 2015). Another functionality is the automated data detection and retrieval, which was applied by Said and El-Rayes (2014) to improve site layout decisions. Boton et al. (2018) outlined different construction aspects that are covered by 4D BIM: communication and collaboration, logistics and site development, analysis of constructability and activity scheduling alternatives.

It can be argued that the use and application of 4D BIM is on the rise, hence extending its capabilities to tackle complex issues. For instance, a recent study by Jupp (2017) proposed an approach using 4D BIM to support environmental planning and management. The study concluded that 4D BIM has provided further opportunities to visualise the significance of environmental impacts and enhance communication as well as information flows between different stakeholders. A similar in nature research has also looked into the use of 4D BIM to perform thermographic visualisations to identify inefficiencies and problems sources of building envelopes (Natephra et al., 2017). The study proposed a method that incorporates the use of 4D BIM, which allows users to view changes in thermal information over time. Another study has developed a logistics planning and control model to simulate site assembly of engineering-to-order prefabricated building systems using 4D BIM (Bortolini et al., 2019). The study supported recognising the synergies between lean principles and 4D BIM functionalities, which was seen as a useful mechanism to recognise further potentials of BIM.

**2.3 Phenomenology and BIM-based Scheduling**

Phenomenology, in its general form, is one of the utilised approaches to qualitative research, which focuses on the commonality of a lived experiences within a particular group. Its fundamental aim is to unpack nature of a particular phenomenon (Creswell, 2013). Phenomenological research, indeed, values people’s experiences in relation to the research being investigated (Balls, 2009). Phenomenological research can be approach using descriptive or interpretative approaches. Descriptive phenomenology uses the concept of bracketing, which involves putting aside the researcher’s own pre-conceptions about the phenomenon being investigated. Interpretative phenomenology, on the other hand, takes the researcher’s pre-conceptions and experiences to interpret meanings (Koch, 1995). In BIM, the phenomenological stance was explored by Boyd et al (2016) in relation to how clients and users perceive digital representations. It was argued that clients’ and users’ perception of digital representation is phenomenological, thus interactive and dynamic visualisations can be more useful. It was concluded that effective representations those that can induce feeling and experience to be more holistic.

With relation to 4D BIM, it can be stated that the abstract conception of BIM’s 4th dimension is that it primarily represents the planning aspect, where in this context, planning is labelled by time. However, over the years, 4D BIM-related published work have embedded the use of the term ‘4D’ to derive specific activities without necessarily linking them to any dimension (Charef et al., 2018). In other words, it did not refer or connect that specific activity back to planning. For instance, many researchers have used 4D to conduct safety analysis (Hu et al., 2008) and safety planning (Ding et al., 2014; Choe and Leite, 2017) for many on-site operations. Other research works have focused on listing the benefits of 4D BIM to the construction industry (Umar et al., 2015; Mallie, 2016). Further research developments have even considered the impact of 4D BIM on improving communication and management (Kiviniemi et al., 2011; Ganah and John, 2017). With taking all of the previous efforts in consideration, it is important to highlight that the primary aim of 4D BIM is being an alternatively useful approach that replaces the traditional project scheduling tools (Koo and Fischer, 2000).

In fact, and taking more of a phenomenological stance, during early days of 4D BIM, one of the major challenges was the usage requirements to perform 4D simulations (Heesom and Mahdjoubi, 2004) and level of detail (LoD) required for the development of 4D simulations (Dawood et al., 2002). These challenges have a direct impact on man-hour requirements to produce 4D BIM simulations. Therefore, it can be stated that regardless of the underlying purpose to utilise 4D, the two key factors are time and effort requirements to perform 4D simulations, which are associated with the 4D BIM application used. According to Fischer (2008), it was stated that 4D BIM Models demand a vast amount of time, and there is a high likelihood of errors, which 4D BIM applications cannot detect. For instance, a study by Boton et al. (2015) has discussed the numerous efforts and time invested in adjusting data imported from the architect’s BIM model in order to correctly link the 3D objects to schedule activities. Interoperability, perhaps, can be seen as one of the obstacles that impact time and effort when generating 4D BIM models. With the introduction of many BIM-based software packages, interoperability is still presently seen as one of the major issues that influence the uptake of BIM applications across the whole life cycle of construction projects (Arayici et al., 2018). Although Industry Foundation Classes (IFCs) and green building XML (gbXML) are used as exchanging schemas between different BIM applications, this does not yet ensure error-free data exchange (Asmi et al., 2015). Hence, and to avoid potential loss of information during the exchange process, practitioners prefer the use of identical software packages such as Autodesk BIM packages (Vysotskiy et al., 2015). However, with 4D BIM applications, they still act as a standalone platform, which are used to link the 3D objects with the schedule.

In recent years, one of the traditional construction scheduling packages namely Asta Powerproject has become a 4D BIM platform (Elecosoft, 2018). Unlike other 4D BIM packages, this software package ventures the scheduling process of activities using the 3D objects, which saves both time and effort as opposing to the creation of construction schedule alone then link it to the 3D objects. With the introduction of such software package, the scheduling process is potentially facing a phenomenological shift. This change of experience in terms of using 4D BIM, consequently induces a phenomenological response. This paper aims to provide a phenomenological exploration of traditional scheduling (activity-based) vs. the 3D Model-based scheduling (object-based) to investigate the potential shift of construction scheduling process. More importantly, captures the planners’ perceptions and how they perceive 4D BIM in term of its role and usability within their practice.

* 1. **Methodology**

Due to the nature of this research, the study uses a phenomenological approach using focus group with project planners and a 4D BIM modeller who work for a UK-based construction company. Phenomenological studies acknowledge individuals’ experiences as the primary epistemological source and explores how this becomes the lived experience of a group. Therefore, in relation to project planning, there is the overall meaning of the task, how standard approaches are developed for this to produce outcomes. As mentioned earlier, the change of experience from using 4D BIM potentially induces a phenomenological response. This experience is then taken forward to the next engagement with the new task thus building up a new practice with expectations and feelings of success. Thus, the importance for project planning in change is how new experience is formed in the practice and whether this is the most appropriate. It is part of the exploration that we believe that the change is producing inappropriate practice based on past feelings rather than generating new positive ones. Hence it can be better to look at less experienced practitioners who are more open to new experiences. The only intervention possible is in the way that people learn, thus for improvement we need to work on creating a positive experience from 4D BIM that is interpreted as being useful. The use of focus group as a phenomenological approach is, in concept, similar to Intepretative Phenomenological Analysis (IPA), which is adopted in psychological studies. It aims to understand different individuals’ concerns, and situate them based on their lived experiences. In total, there were six participants, which included five project planners and one 4D BIM Modeller. It is important to indicate that the company has been utilising the use of 4D BIM for few years across most of the projects they undertake. Amongst the project planners, there were two senior project planners, two with some experience and a trainee project planner. The underlying purpose of involving such range of project planners is that it can potentially invoke different perspectives (Clifford et al., 2016) about the philosophy of scheduling process within their practice. The 4D BIM Modeller’s involvement would intensify the understanding of 4D BIM model’s requirements, and the faced issues as the project evolves. Focus of the questions was upon philosophy of construction scheduling, perspectives on traditional scheduling (activity-based), 4D BIM impact at different stages including tendering, design and construction, perspectives on 3D model-based scheduling (object-based), and future of construction scheduling. Findings are structured using thematic analysis, as this will support deriving comparative analysis between activity-based and object-based scheduling.

* 1. **Results and Analysis**

Philosophy of construction scheduling

The initial inquiry was to gain insights into the planners’ view of construction scheduling, and the responses were:

“*We would look at the tender stage first, then look at method of construction, then I work backwards to the design and procurement.*”…….“*We begin with what the client’s requirements are, key dates for submitting a tender and then what is their expected finishing date, then use our template programme and other programmes from previous projects*”……..“*To give the tender team a guide is to what to be done by when, so when do they estimators need to get all the packages returned by or prices back, then to work on our construction process*”……” *we would generally use a template version from something similar that we built before*”. (PL 1, 2018)

From the above responses, it is realised that philosophy of construction scheduling has differed between the planners. However, majority of the planners have elaborated on role of tendering in shaping the initial schedule so that project key dates are met, work packages to be priced, and appropriate methods of construction are selected. Other responses represented the sequence in which a project schedule goes through. On the one hand, some expressed that method of construction is looked at first before thinking about design and procurement. On the other hand, scheduling begins with a template programme in addition to a programme from previously similar projects.

Perspectives on traditional scheduling (activity-based)

In terms of traditional scheduling, respondents have used the term ‘2D scheduling’, which refers to scheduling using only activities and durations, and the responses were:

“*We are a little bit software led, so we are quite accustomed to Asta powerproject, which predominantly been a 2D software, so we are very comfortable with it*” ……. “*2D scheduling helps us to identify where the peak points are in terms of resource allocation, so we produce some sort of resource histogram*” ……. *“It’s quick, and in a lot of our contracts, we are meant to provide resource histogram, and that also helps with our preliminaries for example*”. (PL 2, 2018)

The above responses show that traditional scheduling (activity-based) forms the comfort zone for the planners. Based on the responses, traditional scheduling supports identifying peak points in terms of resource allocation and in terms of other considerations such as preliminaries.

4D BIM Impact on scheduling across different stages

In order to capture richer insight into 4D BIM impact, the participants were asked about 4D BIM across the tendering, design and construction phases. In terms of the tendering stage, the 4D Modeller stated:

“*I often do not get involved at that stage, but I once had to do a video, but it was more for a presentation purpose than focusing on the actual detail of the project*”. (4D 1, 2018)

The planners commented:

“*In many instances, when we decide to use 4D at the tendering stage, is only for the visualising side of it for the client*” …… “*Only problems that 4D really does not excel at is showing the costly elements, which really are critical to win a project than just the production of fancy 4D visualisation*”. (PL 3, 2018)

The above responses show that 4D BIM is often used, at the tendering stage, to provide the visualisation dimension to the client. However, the planners anticipated that 4D BIM would be useful at such stage, if the visualisation highlights costly elements, so that it provides competitive advantage. In terms of the design stage, most planners thought that 4D BIM is not useful, but one of the senior planners stated:

“*The only way I can see 4D useful is for Buildability. So if you see a certain design, with the use of 4D, you might be able to decide whether you want to change a certain structure*”. (PL 4, 2018)

From the response, it can be realised that 4D BIM can contribute towards ‘buildability’ so that it supports better design decisions. Finally, in terms of the construction process, the planners stated:

“*I think when you have got so many different trades, they will only focus on their item of interest, so in that respect, the 4D gives you that successfully*” …… “*4D tends to support the communication aspect*” …… “*4D benefits in re-sequencing the 2D plan or as a result of 4D, we may end breaking down some tasks to further details*” …… “*In 4D, I think we still lack especially in terms of logistics, so for example, we can show how a wall is being built, but we don’t necessarily show where that wall has to be loaded from, put temporarily*”. (PL 5, 2018)

The 4D Modeller added:

“*It really help the planners to capture more realistic image of what goes on site*” …… “*I, however, need to continually be going through the 3D model itself to check for any more details as the project progresses*” …… “*I found that 4D is great for planners, but mainly on the exterior and envelope of the building, not internally like internal fit outs for example*”. (4D 2, 2018)

From the above responses, the planners stated that 4D BIM is beneficial in terms of recognising different trade works on site, communication and re-sequencing the 2D schedules (activity-based). Furthermore, the 4D Modeller added that 4D BIM supports capturing issues before they occur on site. However, it was stated that 4D BIM is challenging in terms of logistics, the continual update it needs as the design progresses, and that its usage is limited to the exterior and envelope of the building.

Perspectives on 3D-Model based Scheduling (object-based)

As part of the study’s primary aim, it was aimed to look at planners’ perspective on potential of scheduling using a 3D Model (object-based), the responses were:

“*I think that you may be able breakdown some of the activities better, because it’s based on objects*” …… “*I think for the specific job that you would want to do, so if the project is traditional then it will be less risky to do it off a 3D model, but in D&B, which is mostly the case in our projects, you need to ensure that your 3D Model is detailed enough*” …… “*For us, we still plan in 2D and we consider 4D as a bolt on. I think that we find it easier to track changes using our classic 2D scheduling*”. (PL 6, 2018)

From the above responses, it can be stated that planners realise the potential of scheduling using a 3D Model, as this will support capturing more details about different activities. However, utilising such scheduling approach, although appropriate, highly dependent on reliability of the 3D Model, which may pose risk especially in design and build procurement routes. In fact, planners argued that main scheduling will remain using 2D scheduling (activity-based), as it supports tracking changes as the project progresses.

* 1. **Discussion**

**5.1 Towards consensus understanding of 4D BIM Impact**

The analysis showed that 4D BIM’s impact differs depending on the stage and its intended use. For instance, at the tendering stage, it was stated by the 4D Modeller (4D 1, 2018) that 4D BIM’s usefulness would be in terms of visualisation whereas the planners (PL 3, 2018) highlighted that 4D BIM’s usefulness at this stage should be to highlight costly elements using the visualisation. Research efforts, however, mostly considered the functionality of visualisation during the construction stage to detect conflicts (Chavada et al., 2012), monitor progress (Golparvar-Fard et al., 2009) or conducting progress analysis (Moon et al., 2014). Similarly, although most planners did not see the usefulness of 4D BIM during the design stage, it was highlighted that 4D BIM can contribute towards buildability to make better design stages. Consequently, this requires more engagement between the planners and 4D Modellers constructively, so that more benefits of 4D BIM can be gained. In fact, Azhar (2011) highlighted the significance of establishing communication strategy within the BIM process, so that potential errors can be minimised, and more robust decisions can be generated. Compared with tendering and design stages, planners were much aware of 4D BIM benefits during the construction stage (PL 5, 2018), but also indicated that temporary works such as logistics is still limited in 4D BIM. Although many recent studies (e.g. Bortolini et al., 2019) are attempting to tackle logistics-related issues (e.g. loading of wall, scaffolding, etc.) using 4D BIM, the complexity of modelling these logistics remain as the main challenge. In fact, the 4D Modeller stressed the amount of time needed to continually keep monitoring changes on the design, so that it can be incorporated in the 4D Model. Therefore, 4D BIM’s impact across different stages needs to become target-based, so that goals are set within each stage based on the project’s complexity and requirements, which shows the necessity of planners’ experience to drive the use of 4D BIM.

**5.2 Activity-based vs. object-based scheduling**

Based on the analysis, planners stated that traditional 2D scheduling (activity-based) is the main starting point in any project when it comes to scheduling (PL 2, 2018). This is despite the ease of identifying resource peak points and other important considerations such as preliminaries. More importantly, activities tend to provide a description of what happens whereas objects represent the outcomes, and this itself can be experienced differently. As for object-based scheduling, although some planners expressed the potential benefits of capturing more insights about the design, they were aware of the shortfalls that the 3D Model may have (PL 6, 2018). They added that procurement route would be a gamechanger in such instance where a traditional contract will be less risky to the object-based schedule for when compared with design and build where risk is most likely to take place. This consequently demonstrate one of the core outcomes resulted from the phenomenological perspective, which shows that what is experienced inappropriately cannot generate new positives. A recent research by Greenwood and Gledson (2017), which used innovation diffusion theory (Rogers, 2003) showed that 4D BIM is compatible with planners’ current practice, but also concluded that 4D BIM methods can be difficult for planners to understand. Although this research provided valuable insight into the acceptability of 4D BIM by planners, it would not necessarily affect their main practice of scheduling as planners (PL 6, 2018). In other words, planners are still likely to process the scheduling of activities using traditional scheduling, and the use of 4D BIM will mainly be to solidify their decisions. According to Umar et al. (2014), by far, 4D BIM Models neither intelligent nor automated, and cannot enhance the construction schedule automatically. In fact, and reflecting on the planners’ responses towards their philosophy of scheduling (PL 1, 2018), it would be difficult to incorporate these philosophies if scheduling is to be done using 3D Model. This is mainly because construction scheduling does not only target the duration and resource of activities, but also how it affects other aspects such as cost and procurement. Although some research attempts are continuing to demonstrate the potentials of 4D BIM, yet most of the developed tools cannot be generalised, and often are limited to the context where it was applied. Li et al. (2015), for instance proposed a 4D simulation to support resource planning through the use of gaming engine. Therefore, it can be concluded that 4D BIM is useful for the planners, and support affirming their decisions, but a shift towards scheduling through 3D Models is difficult and would require more phenomenological considerations beyond technology itself.

* 1. **Conclusions**

To sum up, this research explored activity-based vs. object-based scheduling, and how would this impact the construction scheduling process. The introduction of 4D BIM has boosted further opportunities to tackle many on-site problems including clashes, logistics management, and enhanced communication between stakeholders. However, the philosophy of scheduling itself is ultimately based on principles that were found since the established of CPM and PERT techniques. This was reflected through the planners’ philosophy of scheduling, who phenomenologically highlighted that they still think in 2D when they schedule the programme of activities. Through the study, the role of 4D BIM across different stages was explored where it was indicated that construction phase is where 4D BIM mostly benefiting despite the issues they faced in previous projects, but future work is needed to identify roles of 4D BIM at the tendering and design stages. Planners argued that, although scheduling of a 3D Model (object-based) might be beneficial to gain richer insights into the design and detailing, they will still schedule in 2D (activity-based). This is because activity-based scheduling allow them to make more informed decisions especially those related to cost and procurement. It was concluded that a shift towards object-based scheduling would require going beyond the complexity of technology itself to take in consideration other phenomenological aspects.

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