THE DEVELOPMENT OF 4D BIM BASED INFRASTRUCTURE CONSTRUCTION TIME PLANNING STANDARD OPERATING PROCEDURE TO ENHANCE COMMUNICATION QUALITY FROM INFRASTRUCTURE CONTRACTOR PERSPECTIVE

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ABSTRACT

4D BIM can be utilized as a visual communication media that simulates construction process, including infrastructure projects, to all stakeholders. One of its benefits is to enhance communication quality that can positively affect infrastructure construction time planning phase, which was one of the most important aspect in contractor's business process. This research used qualitative method through interviews and expert validation to identify main activities in construction time planning phase, 4D BIM role in those activities, and involved stakeholders. As a result, 4D BIM based construction time planning strategy in the form of standard operating procedure and communication flow was developed to be used as guideline references for BIM implementation in Indonesia.

Keywords: BIM, Communication, Construction Time Plan, Standard Operating Procedure

Introduction

Construction schedule need to be systematically planned, so construction manager was expected to find suitable solution for problems that occurred. Construction time planning was needed to determine project duration and could be compared with measured performance (Gledson and Greenwood, 2016). Construction schedule planning involves activity sequencing in space and time dimension, with considering procurement process, resources, spatial limitation, and other things in its process (Eastman, 2014). Construction time plan was traditionally communicated using many forms, but in common, it was delivered in bar chart using scheduling software to determine project's critical paths (Gledson and Greenwood, 2016). Many multi-discipline organizations experiencing conflicts, complexity, uncertainty, and ambiguity in traditional construction practice that could deter information deliverance, which created process duplication (Khosrowshahi, 2012). One of main challenges in construction project planning was its characteristics that need multi-stakeholder knowledge integration and the need of information exchange process that gives better clarity which facilitates communication about complex construction process (Hartmann and Vossebeld, 2013).

BIM model contains geometric attributes that explains construction products in 3D with its time attributes that indicates start and finish dates of these element construction activities. The 4D model can be used to graphically simulates construction process. Therefore, BIM can increase planning efficiency and gives advantages to overall project performance (Yalcinkava, 2013). One of BIM scheduling features enabled user to create, review, and edit schedule through virtual model which was called 4D schedule (Yakoob, 2016). 4D plan is a construction schedule plan that was connected to 3D structural elements to visualize space time relationship of those elements. It facilitates better analysis of construction schedule to assess its implementation results and reduce scheduling error through questioning and validation process (Gledson and Greenwood, 2017). 4D BIM model enabled contractors to simulate and evaluate construction sequence plan and communicate it to other team members (Eastman, 2014).

Although BIM was known as a technology that can improve construction project management quality, its full benefits has not been reached. Integration of BIM and other technology had to be done in parallel with suitable managerial approach and strategy. To take maximum potential of BIM, it was suggested to conduct a research regarding BIM implementation steps in project lifecycle (Wang, 2015), especially in infrastructure projects (Yalcinkava, 2013). Effective BIM implementation needs significant changes in construction business process to take advantages from BIM implementation effective strategy and methodology (Khosrowshahi, 2012). According to Yakoob (2016) through his research in Malaysia, communication in construction organization was one of the key success factors in BIM implementation. In fact, there were collaboration limitations between project's stakeholders that were caused by differences in background and work culture, which was created from construction traditional practices. This will become a barrier in BIM implementation that needs higher collaboration.

BIM needs suitable construction activities coordination (Wang, 2015) that combined several BIM implementation key success factors through BIM process standardization. This was done to directs BIM implementation process that can increase construction process quality, because there were lack of BIM integration guidance in construction practice. Therefore, guidance in BIM implementation development was needed in form of BIM application standardization in construction organization business process, especially for contractors (Yakoob, 2016).

Research Objectives

The objectives of this research were:

a. To identify main activities in infrastructure construction time planning phase (RQ1)
b. To identify stakeholders who were involved in infrastructure construction time planning phase (RQ2)
c. To identify the role of 4D BIM that can be implemented in infrastructure construction time planning phase (RQ3)
d. To develop Standard Operating Procedure and communication flow in 4D BIM based infrastructure construction time planning phase (RQ4)

Literature Review

a. Construction Time Planning

One of essential aspects to ensure construction project delivery success is the accuracy of project planning. Construction project planning stage sets influential framework to major portion of the decision-making process. It was categorized into project development and execution phase, which was one of project lifecycle phase. Although construction project planning involving several planning aspects, time management planning can be stated to be main planning aspect (Syal, et. al, 1992).

According to PMBOK 6th Edition (2017), time management planning was divided into 5 process, i.e. time management planning, defining activities, sequencing activities, estimating activity durations, and schedule development. Time management planning is a process to determine provisions, procedures, and documentations to plan, develop, manage, execute, and control project schedule. Defining activities is an identification and documentation process of specific activities that had to be done to produce project results. Sequencing activities is an identification and documentation process of project activities relationships. Estimating activity durations is an estimating process of activity duration needed to finish certain activity using estimated resources. Schedule development is an analytical process of relationship between activities, durations, resource requirements, and schedule constraints to create project schedule model for project execution, monitoring, and controlling.

b. 4D BIM

Major contractor companies tend to use computer-based system to execute all their works, such as estimation, planning, construction, scheduling, cost controlling, accounting, procurement, supplier management, etc. BIM (Building Information Modelling) is a modelling technology that can be connected to a series of process to produce, communicate, and analyze structural model (Eastman, 2011). BIM enabled scheduler to create, review, and process 4D model (3D BIM model with time parameters) frequently, which will aim to create better and more reliable construction schedule implementation (Eastman, 2011).

In 4D planning process, 4D BIM model was needed to enhance construction planning quality, because it enabled contractors to simulate and evaluate construction sequence plan and distributed it to other stakeholders (Gledson and Greenwood, 2017). 4D BIM functions mainly as a communication tool to show project constraints and a method to enhance collaboration quality, because contractors can communicate construction process to stakeholders visually, present project's influence to surrounding environment, organize logistic area, coordinate activities on project site, and compare schedule and construction progress with ease (Eastman, 2011; Greenwood and Gledson, 2017).

c. Project Communication Management

Communication is an information exchange process, which can be done intentionally or not. Project communication management is a process that was needed to ensure all project information need from its stakeholders can be fulfilled through document development and activity implementation, which was designed to create effective information exchanges. It consists of two parts, strategy development to ensure effectivity of communication and activity implementation to apply communication strategy. Project communication management can be categorized into communication management planning, communication management, and communication monitoring process (PMBOK 6^{th} Ed, 2017).

Project communication was supported by efforts to avoid misunderstanding and miscommunication and was done based on method selection, message, and message sender through careful planning process (PMBOK 6^{th} Ed, 2017). Communication flow of infrastructure construction time planning process can be designed to enhance communication quality. BIM can be utilized as a tool to increase communication quality, especially 4D BIM in construction time planning phase (Eastman, 2011).

Methodology

This research was done using qualitative approach, through literature reviews, a case study, structured interviews, and expert validations. This research was divided into 4 (four) stages, according to its research questions (RQ). Data collecting method and analysis method for each RQ differ from one another, based on its characteristics. Interviewee criteria was also set based on suitable condition to answer research questions. The case study was done in XY company, one of state-owned contractor in Indonesia, especially in the infrastructure projects division. Each stage was done consecutively to avoid errors in data gathering process, because the results from previous stage were needed to execute next research stage. The research methodology can be seen in Table 1.

Table 1. Research Methodology

RQ	Data Collecting Method	Analysis Method	Interviewee Criteria
RQ1	Literature Review, Expert Validation	Data Reduction, Descriptive Analysis	10 years working experience, 5 years as project manager in infrastructure projects
RQ2	Literature Review, Structured Interviews, Case Study, Expert Validation	Descriptive Analysis using RAM RACI	10 years working experience in infrastructure projects
RQ3	Literature Review, Structured Interviews, Case Study	Descriptive Analysis	2 years working experience with BIM
RQ4	Expert Validation	Descriptive Analysis through Standard Operating Procedure and Communication Flow	10 years working experience in infrastructure projects, BIM Managers or Directors

Result and Discussion

a. RQ1

Based on PMBOK 6th Ed (2017), there are 5 (five) stages in construction time planning phase, i.e. time management planning, activity determination, activity sequencing, activity duration estimating, and schedule development. From literature reviews, author can identify 60 main activities in those stages. Using expert validation method with 3 (three) senior project managers that have at least 10 years of experience in infrastructure projects in Indonesia, it can be concluded that the activity variable can be reduced into 58 main activities, as be seen in Table 1.

Table 2. Validated Main Activities in Infrastructure Construction Time Planning Phase

No	Stages	Code	Activity	Reference
X_1	Time Management Planning	X1.1	Acquire design documents	Syal, et. al., (1992)
		X1.2	Initial review for design documents	Syal, et. al., (1992)
		X1.3	Determine planning team	Syal, et. al., (1992)
		X1.4	Determine planning time frame	Syal, et. al., (1992)
		X1.5	Study design documents	Syal, et. al., (1992)
		X1.6	Gather information regarding regulations	Syal, et. al., (1992)
		X1.7	Field survey and investigation	Syal, et. al., (1992)
		X1.8	Study project charter	PMBOK 6th Ed, 2017
		X1.9	Hold meeting with design consultant	Syal, et. al., (1992)
		X1.10	Review project characteristics	Syal, et. al., (1992)
		X1.11	Study scope-of-work management plan	PMBOK 6th Ed, 2017
		X1.12	Determine project development approach	PMBOK 6th Ed, 2017
		X1.13	Review owned resources	Syal, et. al., (1992)
		X1.14	Review subcontractors and suppliers list	Syal, et. al., (1992)
		X1.15	Study previous project plan template and format	PMBOK 6th Ed, 2017
		X1.16	Determine project completion constraints	Syal, et. al., (1992)

No	Stages	Code	Activity	Reference
X1	Time Management Planning	X1.17	Make decision regarding self-management of subcontracted scope-of-work	Syal, et. al., (1992)
		X1.18	Distribute plans and specifications to subcontractors	Syal, et. al., (1992)
		X1.19	Determine level of detail for subcontracted scope-of-work	Syal, et. al., (1992)
		X1.20	Distribute self-management scope of work to planning team	Syal, et. al., (1992)
		X1.21	Determine level of detail for project schedule	Syal, et. al., (1992)
		X1.22	Develop construction project time management plan	PMBOK 6th Ed, 2017
X_2	Activity Determination	X2.1	Hold coordination meeting in planning team	Syal, et. al., (1992)
		X2.2	Determine initial Work Breakdown Structure	Syal, et. al., (1992)
		X2.3	Determine construction method in project level	Syal, et. al., (1992)
		X2.4	Determine project resources	Syal, et. al., (1992)
		X2.5	Apply change request if there are scope-of-work changes	PMBOK 6th Ed, 2017
		X2.6	Determine construction project activity attributes	Syal, et. al., (1992)
		X2.7	Determine construction project activities	PMBOK 6th Ed, 2017
		X2.8	Divide project into milestones	Syal, et. al., (1992)
		X2.9	Apply project milestone	Syal, et. al., (1992)
		X2.10	Develop detailed Work Breakdown Structure	Syal, et. al., (1992)
X_3	Activity Sequencing	X3.1	Hold coordination meeting in planning team	Syal, et. al., (1992)
		X3.2	Choose construction method	Syal, et. al., (1992)
		X3.3	Connect activities with work items	Syal, et. al., (1992)
		X3.4	Determine dependencies and integration between activities	PMBOK 6th Ed, 2017
		X3.5	Determine leads and lags	PMBOK 6th Ed, 2017
		X3.6	Update assumption log	PMBOK 6th Ed, 2017
		X3.7	Determine activity sequence	Syal, et. al., (1992)
		X3.8	Update activity list and its attributes	PMBOK 6th Ed, 2017
X_4	Activity Duration Estimating	X4.1	Hold coordination meeting in planning team	Syal, et. al., (1992)
		X4.2	Collect schedule information from subcontractors	Syal, et. al., (1992)
		X4.3	Determine duration estimation basis	PMBOK 6th Ed, 2017
		X4.4	Determine and calculate productivity	Syal, et. al., (1992)
		X4.5	Calculate duration activity	Syal, et. al., (1992)
		X4.6	Update activity attributes	PMBOK 6th Ed, 2017
		X4.7	Update assumption log	PMBOK 6th Ed, 2017

No	Stages	Code	Activity	Reference
X_5	Schedule Development	X5.1	Hold coordination meeting with stakeholders	Syal, et. al., (1992)
		X5.2	Finalize construction schedule parameters	Syal, et. al., (1992)
		X5.3	Calculate schedule start	Syal, et. al., (1992)
		X5.4	Review project critical path according to actual project time requirements	Syal, et. al., (1992)
		X5.5	Review available and scheduled resources	Syal, et. al., (1992)
		X5.6	Compare schedule with construction cost analysis	Syal, et. al., (1992)
		X5.7	Revise construction schedule if needed	Syal, et. al., (1992)
		X5.8	Determine project calendar	PMBOK 6th Ed, 2017
		X5.9	Update activity attributes	PMBOK 6th Ed, 2017
		X5.10	Update assumption log	PMBOK 6th Ed, 2017
		X5.11	Distribute construction schedule to stakeholders	PMBOK 6th Ed, 2017

b. RQ2

Interviews were conducted to identify the stakeholders involved in infrastructure construction time planning activities that were identified and analyzed from RQ1. As the results, the responsible stakeholders for these activities are owners, consultants, and contractors (detailed into scheduler, engineer, surveyor, quantity estimator, project controller, construction manager, and procurement manager). Most of the activities needed were done by contractors, so it focuses mainly on several functions in contractor company. Based on these data, responsibility assignment matrix (RAM) using RACI (Responsible, Accountable, Consult, Inform) diagram for each activity can be developed based on existing contractor's organizational structure. This matrix can describe clearly the roles and responsibility of each functions in these activities and the relation (coordination) between functions. RAM RACI describes the function's relationship as follows:

- R (Responsible) is the function that carries out the activity
- A (Accountable) is the function that was responsible for the results of the "R" activity
- C (Consult) is the function that can help "R" activities by consultation
- I (Inform) is the function that need to be informed regarding "R" results.

c. RQ3

Based on literature reviews, one of 4D BIM benefits is to enhance communication quality that can positively affect infrastructure construction time planning phase, which was one of the most important aspect in contractor's business process. It can be reached by utilizing 4D BIM to communicate construction process visually, present project effects to surrounding environments, simulate traffic management and project access, simulate logistic area, and simulate material and equipment exchange flow (Eastman, 2011). It can be integrated into infrastructure construction time planning phase in all its stages.

Mainly, there are 5 (five) additional activities that were needed to integrate 4D BIM into construction time planning phase, i.e. 3D surveying (X1.2 Activity Determination), project BIM modelling (X1.2 Activity Determination), analyze additional project activities needed based on project conditions (X1.2 Activity Determination), simulating project activities sequence in 4D BIM (X1.3 Activity Sequencing), and integrating activities in construction schedule to its 3D element (X1.4 Activity Duration Estimating). 3D surveying is needed to illustrate the project area clearly and comprehensively. It could be done using photogrammetry method or laser scanning method. Using 3D BIM modelling technique, the 2D initial design can be illustrated as 3D model and combined with terrain model that was created from 3D surveying. Additional project activities might be needed due to project surrounding environment, such as access roads construction, traffic management, and temporary material storage construction. Afterward, the 4D BIM sequencing could be done by integrating 3D elements of construction objects with its time attributes. From this 4D model, contractor can easily communicate his construction sequence and schedule plan to other stakeholders, also fasten the decision-making process. The 4D BIM models also can be utilized to ease additional judgement regarding construction time management, such as material supply plan, material delivery time, and heavy equipment movement, that can improve the construction schedule.

d. RQ4

Based on previous RQ results (integration between 4D BIM activities and construction time planning activities), responsibility assignment matrix (RAM) using RACI (Responsible, Accountable, Consult, Inform) diagram for each activity, communication flow, and data exchange flow can be developed and adjusted based on contractor company organizational structure, with additional BIM activities. At first, RAM RACI need to be developed to illustrate the correlation between BIM function and other contractor functions in infrastructure contractor companies. Then, the communication flow and data exchange flow can be formed and tailored made, depends on the internal organizational structure of contractor companies or project organizational structure.

Based on 4D BIM activities, some additional functions were needed, i.e. BIM engineer, BIM modeler, and BIM coordinator. Therefore, contractors need to add BIM function into its organizational structure. BIM modeler was needed to illustrate 2D design into 3D BIM models with its required attributes. BIM engineers was needed to analyze the construction sequence and integrating its time attributes into 3D BIM models, so it can be updated into 4D models. BIM coordinator need to supervise BIM department work, integrate multiple discipline design models, and ensure the models were collaborate smoothly (using clash detection method).

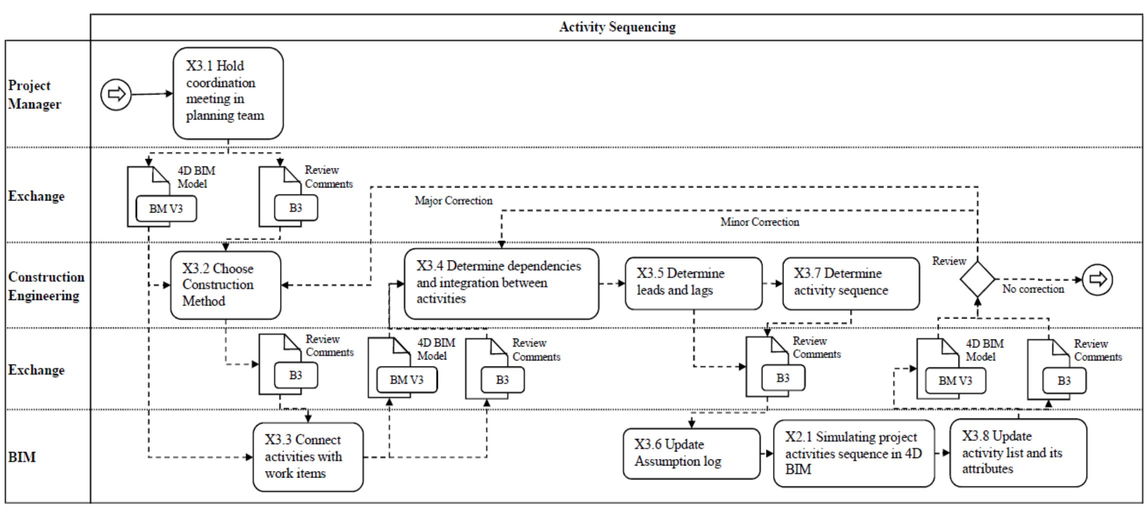

Figure 1. Communication and Data Exchange Flow between Project Manager, Construction Engineer, and BIM Manager in Activity Sequencing Stage in XY Company

Figure 1 shows the example of communication and data exchange flow for activity sequencing stage using 4D BIM technology in XY company. The table row represents the main stages that need to be done to develop construction schedule, which was detailed into smaller activities that illustrated as rectangular shape. The table column represents the parties involved and transitions (data exchanged between functions or parties). In exchange row, the documents flow involved in this process can be shown to minimized error in document delivery. This flow can be adjusted with other contractor company organizational structure, detailed into smaller activities inside each division, and standardized into standard operational procedure, which can be used in other construction projects.

Conclusion

The purpose of this paper is to identify main activities in construction time planning phase, 4D BIM role in those activities, involved stakeholders, and to develop 4D BIM based construction time planning strategy in the form of standard operating procedure and communication flow to be used as guideline references for BIM implementation in Indonesia. Through literature review and expert validation, it can be concluded that there are 58 main activities that was needed to develop construction schedule, that can be categorized into 5 (five) phases (based on PMBOK). These phases are time management planning (22 activities), activity determination (10 activities), activity sequencing (8 activities), activity duration estimating (7 activities), and schedule development (11 activities). Based on interviews results, the responsible stakeholders for these activities are owners, consultants, and contractors (detailed into scheduler, engineer, surveyor, quantity estimator, project controller, construction manager, and procurement manager).

4D BIM can be utilized as a visual communication media that simulates construction process, including infrastructure projects, to all stakeholders. One of its benefits is to enhance communication quality that can positively affect infrastructure construction time planning phase, which was one of the most important aspect in contractor's business process. It can be reached by utilizing 4D BIM to communicate construction process visually, present project effects to surrounding environments, simulate traffic management and project access, simulate logistic area, and simulate material and equipment exchange flow. But, there are some additional activities needed to integrate 4D BIM into construction time planning phase, i.e. 3D surveying, project BIM modelling, analyze additional project activities needed based on project conditions, simulating project activities sequence in 4D BIM, and integrating activities in construction schedule to its 3D element. Therefore, some additional functions were needed, i.e. BIM engineer, BIM modeler, and BIM coordinator. Based on these data, responsibility assignment matrix (RAM) using RACI (Responsible, Accountable, Consult, Inform) diagram for each activity, communication flow, and data exchange flow can be developed and adjusted based on contractor company organizational structure.

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