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ANALYSIS OF THE CRITICAL CHAIN PROJECT MANAGEMENT (CCPM) METHOD, BIM 3D, AND LAST PLANNER SYSTEM ON CONTRACTOR PERFORMANCE AND HIGH RISE BUILDING PROJECT DURATION

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ABSTRACT

This study examines the effectiveness of project implementation by evaluating the impact of Critical Chain Project Management (CCPM), Building Information Modeling (BIM), and the Last Planner System (LPS) on contractor performance and the timeliness of high-rise building projects. Effective scheduling is crucial in construction, as it aims to minimize process time, waiting time, and inventory levels while ensuring the efficient use of resources. The research is motivated by the frequent delays observed in high-rise building projects during the construction phase. The study employed SPSS to analyze data, revealing that the combined use of CCPM, BIM, and LPS significantly improves contractor performance and project implementation time, with a p-value of 0.000, indicating a strong influence. Specifically, the application of the CCPM method reduced the project timeline from 314 days to 235 days, achieving a 33.4% optimization in time. Additionally, the use of BIM 3D modeling facilitated rapid visualization of building progress across different floors, while the implementation of the LPS method improved the Percent Plan Completed (PPC) value from below 70% to 89.49%. The findings suggest that employing these methods enhances the accuracy of project timelines and reduces delays, offering valuable insights into improving construction project management practices.

KEYWORDS *critical chain project management, BIM 3D, last planner system, high rise building, contractor, project implementation time effectiveness*

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INTRODUCTION

Developments in the construction sector are very important in increasing national development which is used as a barometer of national economic growth which also provides job opportunities. Its role in supporting growth and development in various fields, infrastructure development, and as a support for various sectors, one of which is the construction industry. Based on Indonesia's economic growth data report from the Central Statistics Agency (BPS), Indonesia's current economic growth in 2022 reached 5.17%.

Along with Indonesia's economic growth in the last 10 years which has been increasing after the Covid-19 condition, and also Indonesia's geographical location which is at the heart of world economic growth and Indonesia's return to the investment rank with the growth trend of increasing construction investment requires Indonesia to always be ready for changes to accelerate the realization of a developed country with the results of construction development and welfare that can enjoyed equally by all people by increasing Indonesia's Investment Grade so that it becomes a destination country for construction investment in various sectors such as the construction of high-rise buildings, housing, satellite cities, dams, power plants, hospitals, hotels, ports, airports, and especially in investment in the construction of shopping centers which begins with development to support and accommodate economic growth.

The rapid growth in the construction of high-rise buildings is a challenge as a construction actor. The Development Process is supported by construction management and scheduling as an important stage to solve the problem of the success of the construction project. The level of effectiveness of a project can be seen through criteria that include scope, time, quality and cost. All three are known as triple constraints or three constraints. The scope of project work must be met, while time is the project scheduling that must be effective, and the cost is a budget that is in accordance with budgeting. In these three things, technically it is a parameter for the success of a project's activities.

However, the reality that occurs in the field is a common basic problem faced by construction sector actors is delays in project implementation. Globally, projects are delayed by about 40%. This condition describes the lack of time performance in the process of completing construction projects. Delays in project implementation are a reality that often occurs in the construction industry in Indonesia and in other countries, both developed and developing countries (Kholili & Zuhdy, 2023). Delays in the implementation of projects generally always cause detrimental consequences for both owners and contractors because the impact of delays is conflicts and debates about what and who are the cause as well as time and cost demands. Meanwhile, according to research conducted on the construction industry in Malaysia, it is shown that the factors that cause delays in project implementation include improper contractor planning, poor site or field management, contractor experience, inadequate contractor finances, problems with subcontractors, shortage of materials, labor supply and availability and damage to equipment.

In the construction of building projects, there are often delays in their implementation, not in accordance with the timely plan set out in the schedule. In

the high-rise building project in the Bekasi area in the S-curve in December 2023 the planned target is 73.10%, but in the actual implementation it is still 61.65% of the target achieved with a deviation of -11.44%, this can cause delays in project completion. To avoid indications of delays in high-rise building projects, an appropriate model method must be needed to analyze multi-storey building projects to be in accordance with the predetermined planning schedule. In minimizing indications of delays, the company generally strives to be effective in project work time to catch up with work (Fitrianto et al., 2020; Sinaga & Husin, 2021).

There are several methods used in scheduling construction project work time, one of which is CPM (Critical Path Method) scheduling. CPM is a scheduling method by determining the longest duration of the longest chain of events to complete a project (PMBOK, 2018). However, in the reality that occurs in the field, planning using the CPM method and other traditional methods is considered inefficient because it does not consider the productivity of each work in it and related problems due to human behavior that tends to cause an increase in project completion time. Examples are human behavior student's syndrome, Parkinson's law, multitasking and overestimated activity durations (Yusdiana & Satyawisudarini, 2018). So that there has been a development of a new method to become Critical Chain Project Management (CCPM). The CCPM was first introduced in 1997 by Goldratt.

In the case of the previous study, the Critical Chain Project Management method, which was initially 219 working days with the alternative of cutting the duration and adding buffers, obtained the optimal duration result of 206 working days with a decrease of about 6% from the initial schedule by not allowing Multitasking and Parkinson Law (Tampubolon et al., 2021). Then the previous research compared the CPM and CCPM methods in the Menara Rungkut Apartment Development project, Surabaya. The duration for the upper structure work on the scheduling of the Critical Path Method is 169 days, while the duration for the upper structure work on the scheduling of the Critical Chain Project Management is 120.18 days or 121 days, compared in terms of time, the CCPM method is 48 days faster when compared to the CPM method (Rahayu et al., 2022). In the analysis of the previous research, it was also related to the time efficiency of Improving Time Performance with the Building Information Modeling (BIM 3D) and Critical Path Method (CPM) Methods in the Steel Structure Work of Very High-Rise Buildings, which is 9.13% or can be efficient by 21 working days. From the original total work of 230 days, to 209 days (Sinaga & Husin, 2021).

In the research (Aulady & Orleans, 2016) the Last Planner System method of the Jakabaring Flats project, the average result of the Percent Plan Completed (PPC) calculation is 73%. This proves that the LPS Last Planner System method can increase planning reliability above 70% so that the risk of project delays will be smaller. Then from the researcher (Darmanto et al., 2020) stated that the implementation of Lean Six Sigma and the Last Planner System was proven to have an effect on improving cost and time performance in infrastructure work, with cost and time efficiency obtained of 7.82% and 10.21%, respectively.

Research (Adriansyah, 2019) states that contractor performance has an impact of 52.4% on the success of national infrastructure road projects based on long-

segment contracts in Jambi Province. The results of the study (Darmanto et al., 2020) obtained a Customer Satisfaction Index (CSI) value of 0.803 and the results of the Importance Performance Analysis (IPA) analysis show that it can be said that construction project owners are satisfied with the performance of contractors which is the main priority for improving project performance (Sabil, 2023; Taghipour et al., 2020).

In this case, it shows that the project implementation schedule that occurs needs to accelerate the planning of the project implementation schedule. So by using the Critical Chain Project Management (CCPM), Building Information Modeling (BIM) and Last planner System methods as a method of controlling and improving in schedule planning as well as contractor performance and implementation time of time delay problems. The use of (Critical Chain Project Management) CCPM is a project planning method that emphasizes the resources needed to perform tasks in the project and increases the effective project completion rate by analyzing how to eliminate multitasking, student syndrome, Parkinson's law and buffers time at the end of the project and analysis of digital construction technology and get efficient planning results and in controlling the implementation of hotel building work more effectively while the Last Planner System is part of Lean Construction which functions to control production in planning, scheduling and project execution, so that it can improve the linkage and flow between work, performance and productivity of a project construction (Kholili & Zuhdy, 2023). This method is renewable and systematic which can show the percentage of project implementation value through the Percent Plan Complete value and at the same time show the cause of not achieving the implementation of the project that should be in accordance with the project plan through the analysis of Reason Not Completion (Andiyan et al., 2021). Based on the above, this study will examine and analyze how much the implementation of contractor performance efficiency and time in the implementation of high rise building projects, based on the CCPM (Critical Chain Project Management) scheduling method, Building Information Modeling (BIM) 3D, and the Last Planner System can generate a time schedule which is more accurate and efficient so that it can improve contractor performance and time to project implementation.

RESEARCH METHOD

Data Collection Methods

The data of this study was obtained from the following sources:

1. Data Primer

   Primary data was obtained directly from data sources at the research site. This primary data, the source of data is taken from data through questionnaires. In this study, it was carried out by distributing questionnaires to consultants and contractors who are working on high rise building projects. In this study, the data source was taken from the data through questionnaires that were shared with respondents directly, as well as through direct observation of research objects such as Project Managers, Site Engineers, Project Engineers, BIM Modellers, and drafters from other construction service companies.

A questionnaire is a statement that is submitted to respondents in writing, using a list of questions related to the question being researched. Questionnaires are an efficient method of obtaining data when researchers know who the variables are measured and what the respondents expect (Sugiyono, 2016).

2. Data Seconds

Secondary data is an indirect source of data that provides data to data collectors (Sugiyono, 2016). In this study, secondary data was obtained based on materials, literature and reviews of books, journals and historical reports including historical data on the construction of multi-storey buildings, data collected, namely historical data or timeline of project quantity estimation, drawing data obtained from contractors and planners, digital data of BIM (Building Information Modeling) systems) obtained by making model drawings.

Data Analysis Methods

Data analysis is a way to process data into information data so that the characteristics of the data are easy to understand and useful for problem solving, adjusted to the purpose of the research. In this study, data analysis was carried out using SPSS tools to determine the validity test, T test, F test, simultaneous regression analysis and hypothesis test on the variables of this study.

Then for testing the hypothesis of the relationship between variables in a model, the research was carried out using the Structural Equation Model (SEM) approach based on Partial Least Square (PLS). PLS is a structural saman model (SEM) that is component- or variant-based. Structural Equation Model (SEM) is one of the fields of statistical study that can test a series of relationships that are relatively difficult to measure simultaneously. According to Santoso (2014) SEM is a multivariate analysis technique which is a combination of factor analysis and regression analysis (correlation), which aims to test the relationship between variables in a model, be it between indicators and their constructs, or the relationship between constructs.

According to Latan and Ghozali (2012), PLS is an alternative approach that shifts from a covariance-based SEM approach to a variant-based approach. SEM based on covariance generally tests causality or theory while PLS is more of a predictive model. However, there is a difference between covariance-based SEM and component-based PLS is in the use of structural equation models to test theories or develop theories for prediction purposes.

The analysis technique in this study uses the PLS technique which is carried out in two stages, namely:

1. The first stage is to test the measurement model, which is to test the validity and reliability of the construct of each indicator.
2. The second stage is to conduct a structural model test which aims to find out whether there is an influence between variables/correlations between the construction constructs measured using the t-test of the PLS itself.

This study is quantitative descriptive research with survey and descriptive methods that describe the data that has been collected without making conclusions

that apply to the general public or generalization (Sugiyono, 2013). The researcher will discuss problems in the application of Critical Chain Project Management, BIM 3D, Last Planner System (LPS) to contractor performance and the implementation time of the High rise Building project.

RESULT AND DISCUSSION

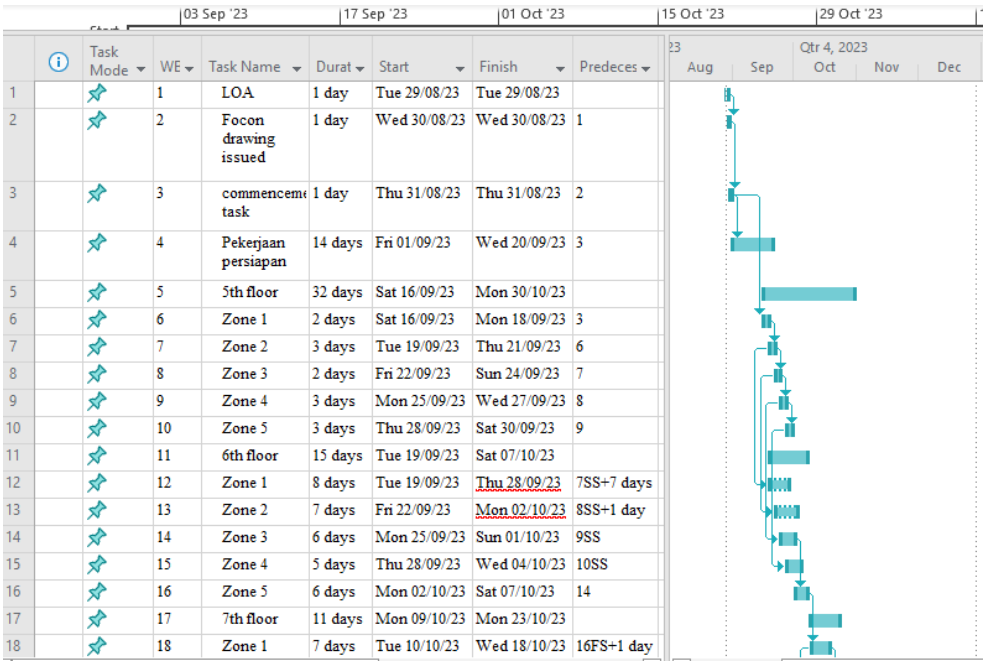
Implementation Critical Chain Project Management (CCPM)

Implementation Schedule

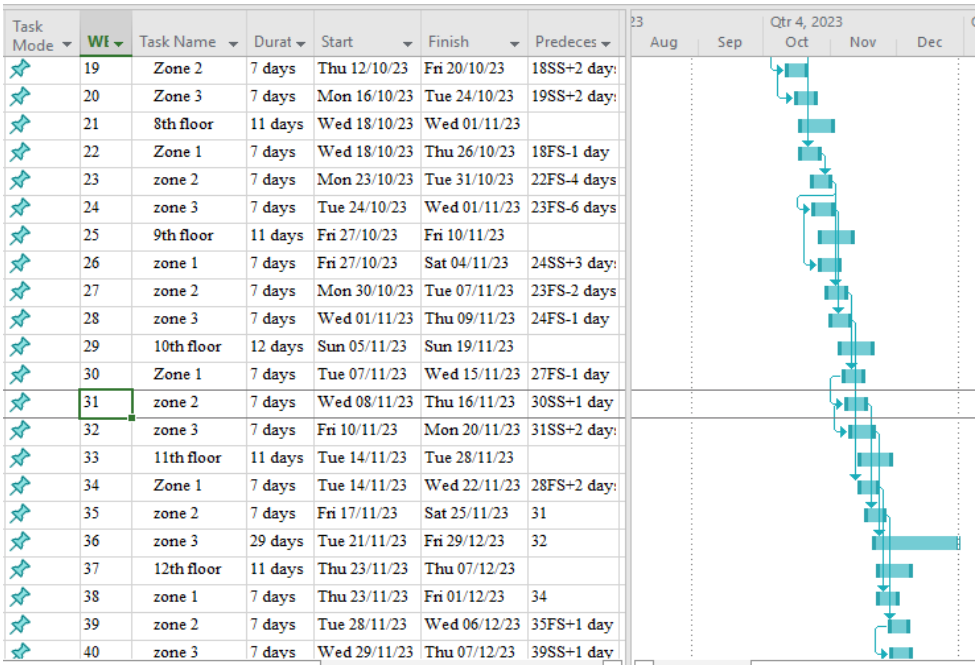
In the implementation of the High rise Building construction project activities, it is carried out every Monday to Sunday at 08.00 WIB until 17:00 WIB with a break time of approximately one hour starting from 12:00 WIB to 13:00 WIB with the time of work implementation per day is 8 hours a day.

Project scheduling analysis

The duration of the project, which is planned and implemented at the preparation stage until the implementation of the construction of high rise bulding up to the 12th floor, is for 314 days consisting of several zones. The project scheduling of the data obtained will be calculated for duration in the process of implementing high rise building structure work using the MS. Project 2021 application which will apply the CPM (Critical path Method) method and the Critical Chain Project Management method (CCPM). The difference between the two methods is a reduction in time in the CCPM method, but in data processing the CPM and CCPM methods are no different from the first one with the compiler of WBS from the data that has been obtained to obtain work activity activities in the implementation of the project according to the information data. The process of breaking down activities into smaller and easier elements in implementation is called Work Breakdown Structure (WBS).



	Task Mode	WE	Task Name	Durat	Start	Finish	Predeces
1		1	LOA	1 day	Tue 29/08/23	Tue 29/08/23	
2		2	Focon drawing issued	1 day	Wed 30/08/23	Wed 30/08/23	1
3		3	commenceme task	1 day	Thu 31/08/23	Thu 31/08/23	2
4		4	Pekerjaan persiapan	14 days	Fri 01/09/23	Wed 20/09/23	3
5		5	5th floor	32 days	Sat 16/09/23	Mon 30/10/23	
6		6	Zone 1	2 days	Sat 16/09/23	Mon 18/09/23	3
7		7	Zone 2	3 days	Tue 19/09/23	Thu 21/09/23	6
8		8	Zone 3	2 days	Fri 22/09/23	Sun 24/09/23	7
9		9	Zone 4	3 days	Mon 25/09/23	Wed 27/09/23	8
10		10	Zone 5	3 days	Thu 28/09/23	Sat 30/09/23	9
11		11	6th floor	15 days	Tue 19/09/23	Sat 07/10/23	
12		12	Zone 1	8 days	Tue 19/09/23	Thu 28/09/23	7SS+7 days
13		13	Zone 2	7 days	Fri 22/09/23	Mon 02/10/23	8SS+1 day
14		14	Zone 3	6 days	Mon 25/09/23	Sun 01/10/23	9SS
15		15	Zone 4	5 days	Thu 28/09/23	Wed 04/10/23	10SS
16		16	Zone 5	6 days	Mon 02/10/23	Sat 07/10/23	14
17		17	7th floor	11 days	Mon 09/10/23	Mon 23/10/23	
18		18	Zone 1	7 days	Tue 10/10/23	Wed 18/10/23	16FS+1 day



Task Mode	WI	Task Name	Durat	Start	Finish	Predeces
	19	Zone 2	7 days	Thu 12/10/23	Fri 20/10/23	18SS+2 days
	20	Zone 3	7 days	Mon 16/10/23	Tue 24/10/23	19SS+2 days
	21	8th floor	11 days	Wed 18/10/23	Wed 01/11/23	
	22	Zone 1	7 days	Wed 18/10/23	Thu 26/10/23	18FS-1 day
	23	zone 2	7 days	Mon 23/10/23	Tue 31/10/23	22FS-4 days
	24	zone 3	7 days	Tue 24/10/23	Wed 01/11/23	23FS-6 days
	25	9th floor	11 days	Fri 27/10/23	Fri 10/11/23	
	26	zone 1	7 days	Fri 27/10/23	Sat 04/11/23	24SS+3 days
	27	zone 2	7 days	Mon 30/10/23	Tue 07/11/23	23FS-2 days
	28	zone 3	7 days	Wed 01/11/23	Thu 09/11/23	24FS-1 day
	29	10th floor	12 days	Sun 05/11/23	Sun 19/11/23	
	30	Zone 1	7 days	Tue 07/11/23	Wed 15/11/23	27FS-1 day
	31	zone 2	7 days	Wed 08/11/23	Thu 16/11/23	30SS+1 day
	32	zone 3	7 days	Fri 10/11/23	Mon 20/11/23	31SS+2 days
	33	11th floor	11 days	Tue 14/11/23	Tue 28/11/23	
	34	Zone 1	7 days	Tue 14/11/23	Wed 22/11/23	28FS+2 days
	35	zone 2	7 days	Fri 17/11/23	Sat 25/11/23	31
	36	zone 3	29 days	Tue 21/11/23	Fri 29/12/23	32
	37	12th floor	11 days	Thu 23/11/23	Thu 07/12/23	
	38	zone 1	7 days	Thu 23/11/23	Fri 01/12/23	34
	39	zone 2	7 days	Tue 28/11/23	Wed 06/12/23	35FS+1 day
	40	zone 3	7 days	Wed 29/11/23	Thu 07/12/23	39SS+1 day

Figure 1. Results of Data Processing Using the CPM Method
(Source: Microsoft Project 2021 data processing results)

The process in its implementation is by optimizing the time (buffer time) by cutting the time (crashing time) from the Critical Path Method (CPM) method by 50% probability. This reduction aims to eliminate safety times so that problems such as Student's Syndrome, Parkinson's Law, Multitasking, and Overestimated Activity Durations can be eliminated. In determining the critical path using the Ms project 2021 program in the calculation of Critical Path Management (CPM) with the following display of work and critical paths,

Table 1. Identification of Critical Paths on the Time Schedule of the Plan

Task Name	Duration
Preparatory work	14 days
5th floor	32 days
Zone 1	2 days
Zone 2	3 days
Zone 3	2 days
Zone 4	3 days
Zone 5	3 days
6th floor	15 days
Zone 1	8 days
Zone 2	7 days
Zone 3	6 days
Zone 4	5 days
Zone 5	6 days
7th floor	11 days
Zone 1	7 days

Zone 2	7 days
Zone 3	7 days
8th floor	11 days
Zone 1	7 days
zone 2	7 days
zone 3	7 days
9th floor	11 days
zone 1	7 days
zone 2	7 days
zone 3	7 days
10th floor	12 days
Zone 1	7 days
zone 2	7 days
zone 3	7 days
11th floor	11 days
Zone 1	7 days
zone 2	7 days
zone 3	29 days
12th floor	11 days
zone 1	7 days
zone 2	7 days
zone 3	7 days
total	314

Source: Results of S Schedule progress curve data , 2024

Reduction of Activity Duration

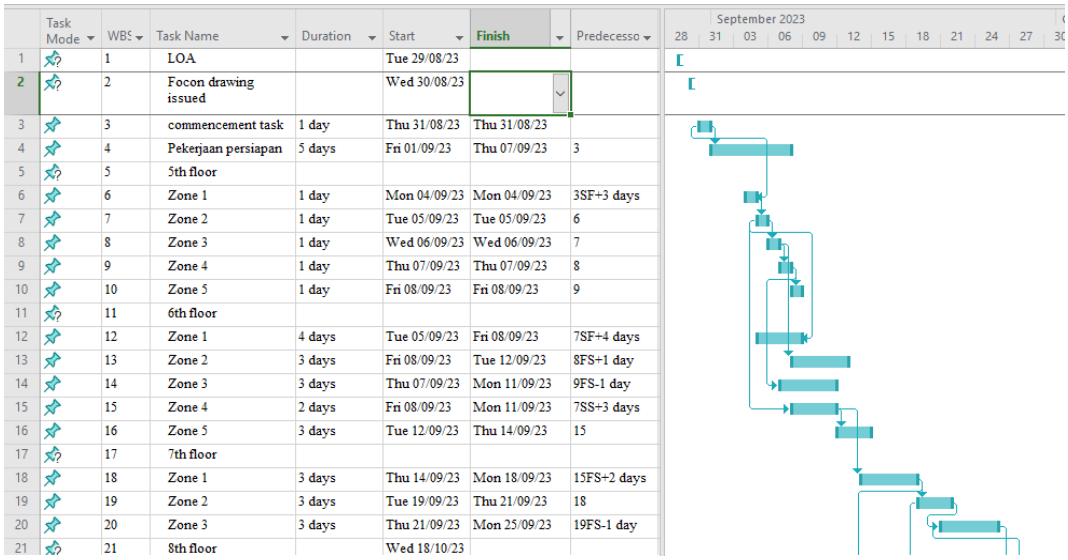
The results of the analysis carried out by the Critical Chain Project Management (CCPM) In developing a schedule with the CCPM method, what needs to be done is to eliminate the safety time (hidden safety) by using a 50% probability of execution time to complete each job. The duration of each job after the 50% probability estimate can be seen in the attachment 50% Probability Estimate Job Duration Table.

Table 2. Identification of Critical Paths After Conducting with the CCPM Method

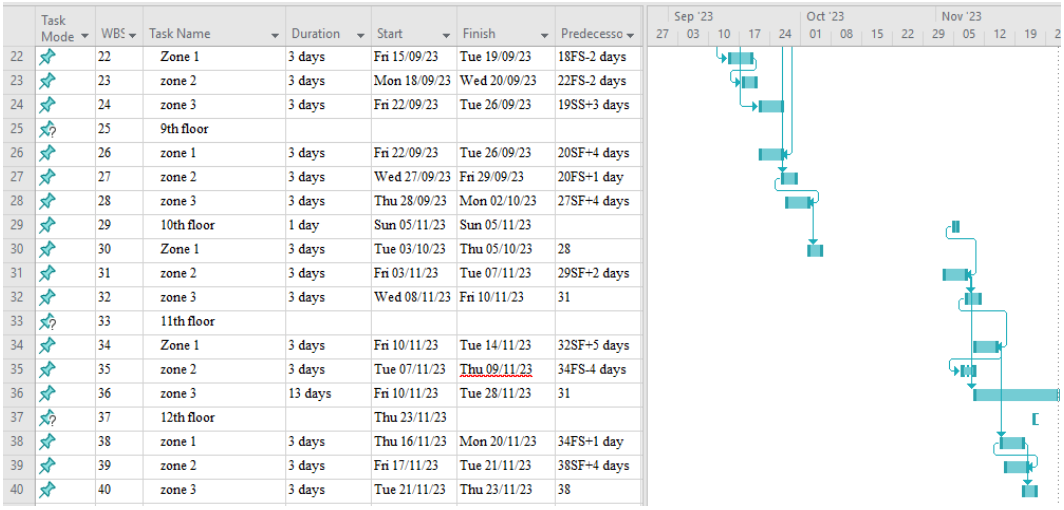
Task Name	Duration
Preparatory work	7 days
5th floor	16 days
Zone 1	1 days
Zone 2	1,5 days
Zone 3	1 days
Zone 4	1,5 days
Zone 5	1,5 days
6th floor	7,5 days
Zone 1	4 days
Zone 2	3.5 days
Zone 3	3 days

Zone 4	2,5 days
Zone 5	3 days
7th floor	5,5 days
Zone 1	3,5 days
Zone 2	3,5 days
Zone 3	3,5 days
8th floor	5,5 days
Zone 1	3,5 days
zone 2	3,5 days
zone 3	3,5 days
9th floor	5,5 days
zone 1	3,5 days
zone 2	3,5 days
zone 3	3,5 days
10th floor	6 days
Zone 1	3,5 days
zone 2	3,5 days
zone 3	3,5 days
11th floor	5,5 days
Zone 1	3,5 days
zone 2	3,5 days
zone 3	14,5 days
12th floor	5,5 days
zone 1	3,5 days
zone 2	3,5 days
zone 3	3,5 days
total	157

Source: S curve data processing Schedule progress



	Task Mode	WBS	Task Name	Duration	Start	Finish	Predecesso
1		1	LOA		Tue 29/08/23		
2		2	Focon drawing issued		Wed 30/08/23		
3		3	commencement task	1 day	Thu 31/08/23	Thu 31/08/23	
4		4	Pekerjaan persiapan	5 days	Fri 01/09/23	Thu 07/09/23	3
5		5	5th floor				
6		6	Zone 1	1 day	Mon 04/09/23	Mon 04/09/23	3SF+3 days
7		7	Zone 2	1 day	Tue 05/09/23	Tue 05/09/23	6
8		8	Zone 3	1 day	Wed 06/09/23	Wed 06/09/23	7
9		9	Zone 4	1 day	Thu 07/09/23	Thu 07/09/23	8
10		10	Zone 5	1 day	Fri 08/09/23	Fri 08/09/23	9
11		11	6th floor				
12		12	Zone 1	4 days	Tue 05/09/23	Fri 08/09/23	7SF+4 days
13		13	Zone 2	3 days	Fri 08/09/23	Tue 12/09/23	8FS+1 day
14		14	Zone 3	3 days	Thu 07/09/23	Mon 11/09/23	9FS-1 day
15		15	Zone 4	2 days	Fri 08/09/23	Mon 11/09/23	7SS+3 days
16		16	Zone 5	3 days	Tue 12/09/23	Thu 14/09/23	15
17		17	7th floor				
18		18	Zone 1	3 days	Thu 14/09/23	Mon 18/09/23	15FS+2 days
19		19	Zone 2	3 days	Tue 19/09/23	Thu 21/09/23	18
20		20	Zone 3	3 days	Thu 21/09/23	Mon 25/09/23	19FS-1 day
21		21	8th floor		Wed 18/10/23		



	Task Mode	WBS	Task Name	Duration	Start	Finish	Predecesso
22		22	Zone 1	3 days	Fri 15/09/23	Tue 19/09/23	18FS-2 days
23		23	zone 2	3 days	Mon 18/09/23	Wed 20/09/23	22FS-2 days
24		24	zone 3	3 days	Fri 22/09/23	Tue 26/09/23	19SS+3 days
25		25	9th floor				
26		26	zone 1	3 days	Fri 22/09/23	Tue 26/09/23	20SF+4 days
27		27	zone 2	3 days	Wed 27/09/23	Fri 29/09/23	20FS+1 day
28		28	zone 3	3 days	Thu 28/09/23	Mon 02/10/23	27SF+4 days
29		29	10th floor	1 day	Sun 05/11/23	Sun 05/11/23	
30		30	Zone 1	3 days	Tue 03/10/23	Thu 05/10/23	28
31		31	zone 2	3 days	Fri 03/11/23	Tue 07/11/23	29SF+2 days
32		32	zone 3	3 days	Wed 08/11/23	Fri 10/11/23	31
33		33	11th floor				
34		34	Zone 1	3 days	Fri 10/11/23	Tue 14/11/23	32SF+5 days
35		35	zone 2	3 days	Tue 07/11/23	Thu 09/11/23	34FS-4 days
36		36	zone 3	13 days	Fri 10/11/23	Tue 28/11/23	31
37		37	12th floor		Thu 23/11/23		
38		38	zone 1	3 days	Thu 16/11/23	Mon 20/11/23	34FS+1 day
39		39	zone 2	3 days	Fri 17/11/23	Tue 21/11/23	38SF+4 days
40		40	zone 3	3 days	Tue 21/11/23	Thu 23/11/23	38

Figure 2. Data Processing Results Using the CCPM Method, Schedule Eliminated 50% Security Time (Hidden Safety)
(Source: Microsoft Project 2021 data processing results)

The relationship of activity dependence between critical chain based on the activity itself. The activity is related to Finish to start as in table 4.13. In some works on each floor that covers several zones can be done with 100% and this is due to the high number of work entanglements or called critical paths/activities. By relationship finish to start so there is a problem in the work chain to be longer than overlapping. Before the method is carried out CCPM or still by using CPM The duration of the project schedule was 314 days.

So that scheduling with the CCPM by eliminating time Safety of each job using a 50% probability of the job time to complete each job. As shown in table 4.17, the CCPM method has been implemented with a crashing of 50% on each work from planning to the 12th floor in the last zone. The duration obtained from this method is 157 days.

Feeding Buffer and Project Buffer on CCPM scheduling

With the reduction in time in scheduling, it is possible if the project carried out is delayed more. Therefore, to minimize the project from delays, it is necessary to include project buffer at the end of the critical chain. The calculation of the buffer project size is calculated using the CCPM that is, 50% of the overall project implementation time on work that is on the critical path.

$$Project\ buffer = 50\ \%\ x\ Jumlah\ durasi\ pekerjaan\ kritis$$

So that the calculation is obtained:

$$Project\ buffer = 50\ \%\ x\ 157\ hari$$

$$= 78.5 \text{ days}$$

Feeding buffers are added in scheduling at the intersection between critical chain and non-critical chain work. The value of this feeding buffer is measured by measuring 50% of the non-critical chain length. The following is the determination of the feeding buffer in scheduling the critical chain in non-critical work (Suherman and Ade Aulia, 2016)

$$Feeding\ buffer = \sum \quad durasi\ x50\ \%$$
$$Feeding\ buffer = (5+1) hari\ x\ 50\ \%$$
$$Feeding\ buffer = 6\ hari\ x\ 50\ \%$$
$$Feeding\ buffer = 3\ hari$$

So that from the scheduling data obtained on the duration of the implementation of high rise building at the beginning of 314 days after rescheduling with the optimization method using Critical Chain Project Management (CCPM) obtained time optimization from the buffer project as follows:

Initial duration = 314 Days
Project Duration Buffer = 78,5
Day of Reduction = 314 Days – 78.5 Days
= 235,5
=235 days

So time optimization by applying critical chain project management is Time Optimization = 33.4 %$\frac{78,5}{235}\ x\ 100\% =$

So, with the implementation of critical chain project management, time optimization of 33.4% was obtained, which will then be implemented to the next method, namely the 3D building information modeling method.

Implementation Building Information Modeling (BIM) 3D

In this study, the case study will explain the application of 3D Building Information Modeling (BIM) to high rise building structure work by explaining the procedures and concepts of application to 3D BIM. The output of 3D modeling can visualize 2D images on overlapping jobs such as structure work with MEP work in 3D BIM modeling. 3D modeling can minimize conflicts so that during the process of carrying out work can be done in the field in accordance with BIM 3D modeling, avoiding clash detection between other work installations. The results of BIM 3D can be seen how the visualization of the progress of the implementation of building work on each floor is carried out in the form of images.

Application of Last Planner System (LPS)

Last planner system It is intended to find out whether using the last planner system can increase the reliability of work with PPC >75%. Research conducted by applying the last planner system in a project scheduling:

a. Master Schedule / milestone schedule
b. Phase Planning dan Pull Planning
c. Lookahead Planning
d. Constraint analysis
e. Shielding production
f. Weakly Work Plan (WWP)
g. Analisa Should-Can-Will-Did
h. Percent Plan Completed (PPC)

According to (Ballard, 2000), the Percent Plan Complate (PPC) is the number of assignments that have been completed divided by the number of all planned assignments, and written in the form of a percentage.

$$Percent\ Plan\ Completed\ (PPC)\ (\%) = \frac{number\ of\ completed\ task}{number\ of\ assigned\ task}\ x\ 100\%$$

Percent Plan Complate (PPC) is used as a standard to control production units, determine project schedules, implementation strategies, and others. A PPC value of > 75% indicates that the work is completed with high productivity and fast progress with available resources.

Information stage

Based on the projects carried out in this study, the description of the projects studied is as follows:

Project name : Hotel Living World Bekasi
Building Development : Hotel
Location : Bekasi, West Java
Building Category : Commercial Building
Number of floors of the building:

- 1 Basement
- 3 Podium Floors
- 9 floors of hotel rooms
- Total 17 multi-storey floors

The scope of work is as follows:

The work of 17 floors of multi-storey buildings grouped by work components, includes:

The scope of work consists of:

- Structural Work
- Column, Beam, Corewall and Plate Ironing Work
- Column and Beam Separator Ironing Work
- Stair Ironing Work
- Formwork of Columns, Beams, Corewalls, and Plates
- Formwork of Separator Columns and Beams
- Stair Formwork Work
- Concrete Cast Work Columns, Beams, Corewall and Slabs
- Concrete Cast Column and Beam Separator Work
- Stair Concrete Cast Work

The location of the project is described as follows:

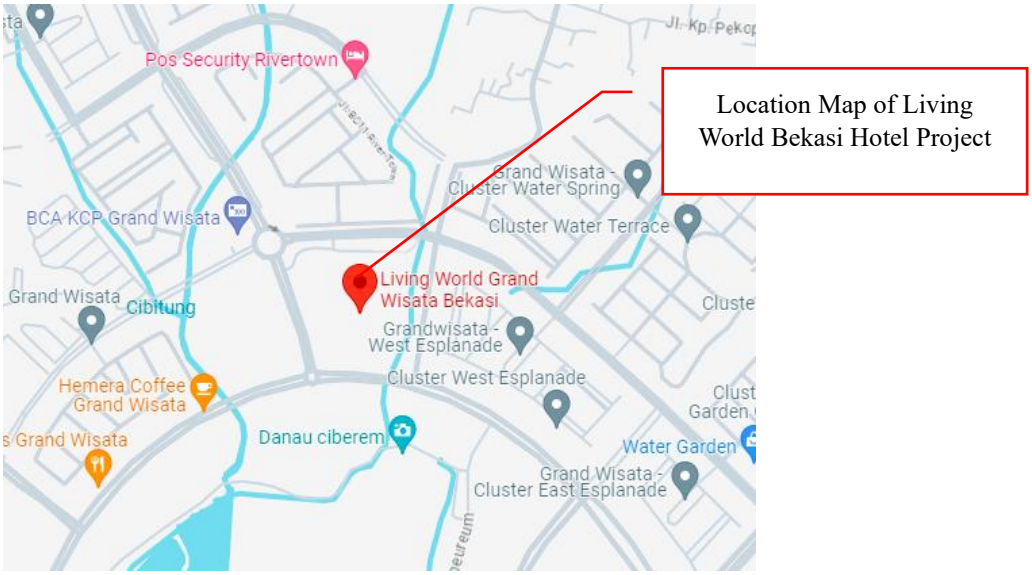


Figure 3. Location of the project

From the data using the calculation of the Last Planner system, it was obtained that the value of PPC using the equation was 89.497%. This value is appropriate and accurate because the implementation using PPC is said to be inappropriate if the average value is less than 70%. With an increase in the accuracy of the implementation time so that it can reduce the delay time.

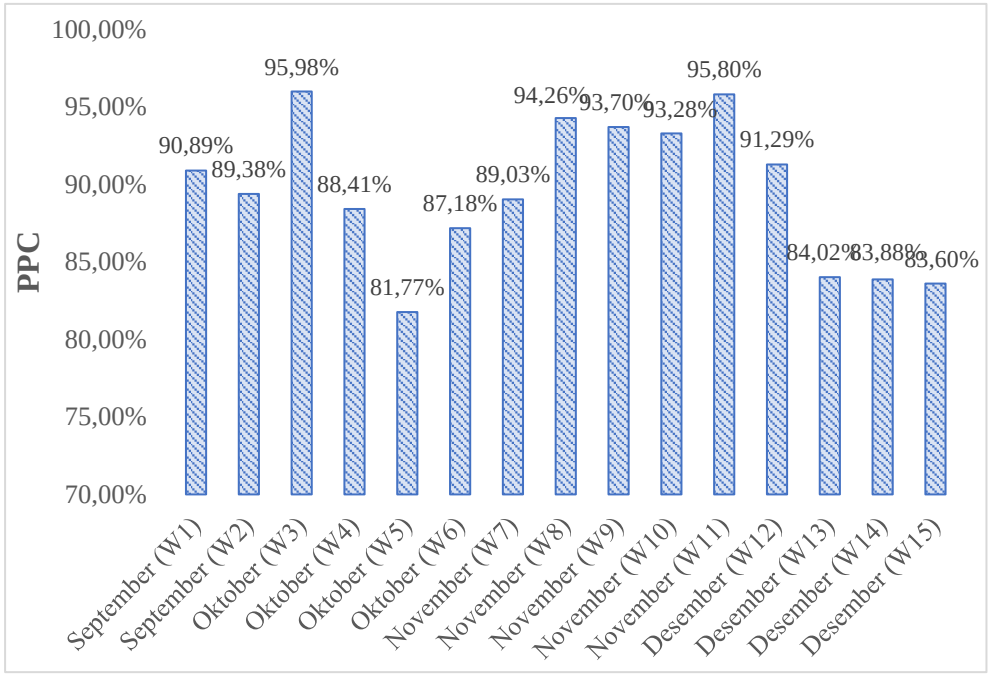


Figure 4. PPC Value
(Source: Self-processed, 2024)

CONCLUSION

The application of Critical Chain Project Management (CCPM) can optimize high-rise building project schedules, reducing implementation time by 33.4% when the entire buffer is utilized, resulting in an optimal project duration of 157 calendar days. Building Information Modeling (BIM 3D) effectively visualizes overlapping structural work, minimizing clashes and enhancing progress monitoring through 3D images. The Last Planner System (LPS) supports schedule accuracy, as shown by a Percent Plan Complete (PPC) value of 89.497%, well above the acceptable threshold of 70%, indicating improved time accuracy and reduced delays.

Statistical analysis using SEM-PLS and SPSS 27 reveals that BIM 3D significantly impacts contractor performance, while CCPM and LPS individually do not. However, when assessed collectively through the F-test, CCPM, BIM 3D, and LPS simultaneously influence contractor performance, as indicated by a significance value of 0.000 and an F value of 31.815, exceeding the F table value of 2.80. Furthermore, contractor performance significantly affects project implementation time, supported by a high parameter coefficient of 0.787 and a significant p-value of 0, confirming a strong relationship between contractor performance and project timeline success.

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