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Dynamic Modeling of Time Cost Trade off in Design and Build Projects of high Rise office Buildings

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ABSTRACT

This paper aims to determine the impact of accelerated duration on profit and contingency costs. The method uses the design and build project of a high-rise office building, which begins with an analysis of the actual project schedule, the possibility of accelerating the duration with the assumption of additional working hours for workers and the impact of perceived duration on project costs. Then proceed with System Dynamic (SD) modeling with reference to the Time Cost Trade Off theory and end with a scenario of the relationship between project activity acceleration, profit addition and crashing costs. Project acceleration can improve project performance by considering the effect on profits and contingency costs, with a Schedule Performance Index (SPI) of up to 37.8%, it can increase profits between 4.08% due to reduced indirect costs.

Key word: time cost trade off; dynamic system; office high rise building; shedule performance index; design and build

INTRODUCTION

Design and build projects that are starting to gain interest in the development journey in the construction sector. Design and build projects in the world of construction are expected to increase from 42% to 47% in 2020 to 2030. Office construction for design and build projects will cost USD 46 billion (Design-Build Institute of America, 2021).

In Law no. 18 of 1999, the model for combining planning and development (design and build) is regulated in Article 16 paragraph (3) which states that planning, implementation and monitoring services can be carried out in an integrated manner by taking into account the amount of work or costs, the use of advanced technology, and risks for the parties or the public interest in a construction work.

Apart from that data from the 2019 survey of 1778 projects, 63% experienced cost overruns (Husin, 2019). Specifically, global construction cost overruns reached an average of 30.7 million USD and the average time delay reached 15 months (Roy Cooper, 2020). The Global Construction Survey, 2021 stated that 37% of owners and contractors experienced schedule failures and costs reached more than 20% of planning costs and time.

Figure 1. Schedule Failure and Costs for the Owner and Contractor Source: Global Construction Survey 2021

So we need a method that can complete the project on time from the specified schedule, on the other hand, acceleration of the duration of the project can be done to overcome the problem of delays without reducing project profits. So that a suitable method is Time Cost Trade Off with Dynamic System integration to determine the impact of accelerated project duration that implements system dynamic thinking to analyze scenarios of the relationship between accelerated project duration, additional benefits and crashing costs, so as to find innovative solutions to improve project performance.

The project reviewed is a design and build project for a high-rise office building, with technical specifications and data reviewed from the data. One of the recommended steps is to speed up the duration during the construction period. Based on the recommendations for accelerating the duration to improve project performance, it is necessary to analyze the impact on the components of the contract value, based on the components of direct and indirect costs, profits and contingency costs.

This research begins with the manufacture and development of actual costs and actual time by applying crasing in each project activity on the track. Second, scenarios of the relationship between accelerated project duration, contractor incremental profits and crash costs are developed, and apply them to CLD and SFD. From the results of this scenario, suggestions and recommendations will be formed to help contractors overcome delays or at the request of the project owner to save indirect costs. It is hoped that this research can help contractors to increase profits in construction and can also solve problems that arise related to project performance.

RESEARCH METHODS

Causal Loop Diagrams (CLD)

In developing the CLD, interviews were conducted to identify the design and build process of a high-rise office building project. In order to obtain information on the cost and time of the contract with the actual cost and time of the project. The preparation of a network diagram is the first step that must be taken in applying the time cost trade off analysis. In preparing the network diagram, it is necessary to know the relationship between activities and the duration of each activity in accordance with the project schedule. So that the grouping of work for each floor is made according to the project schedule and budget plan. The duration of project completion is determined based on consideration of several factors that influence its completion, namely the volume of work, worker productivity, tool productivity, project location, and resource availability. The One Tower project work must be accelerated during its implementation if it will not experience delays, the initial duration of implementation is 594 days with an agreed initial schedule of 560 days. base model was developed from previous research and policies that describe the relationship between variables and other variables in the model during normal conditions without accelerating the duration of the initial process (budgeting costs to monitoring performance schedules). This model was carried out based on the following literature:

a. The calculation of overtime pay refers to the Decree of the Minister of Manpower No: KEP-72/MEN/84 concerning the basis of overtime pay. According to the Decree of the Minister of Manpower Number: KEP.102/MEN/VI/2004 article 11, wages for working hours (overtime) are calculated as follows: For the first 1 hour of overtime work, the wages to be paid are 1.5 times the hourly wage and every the next working hour, the wages to be paid are 2 times the hourly wage.

b. The index of decreasing productivity due to overtime every hour is 10% (S.Pratama et al, 2019)

c. Indirect costs are the variable costs required to complete the project. These costs are project management fees, project invoices, license fees, insurance, administration, stationery. Indirect costs must include, among others: Fixed salaries and allowances for the management team, Construction Equipment Vehicles, Construction of temporary facilities, Costs for maintaining and using disposable items, Overhead. Costs for the entire operation of the company, Taxes and insurance

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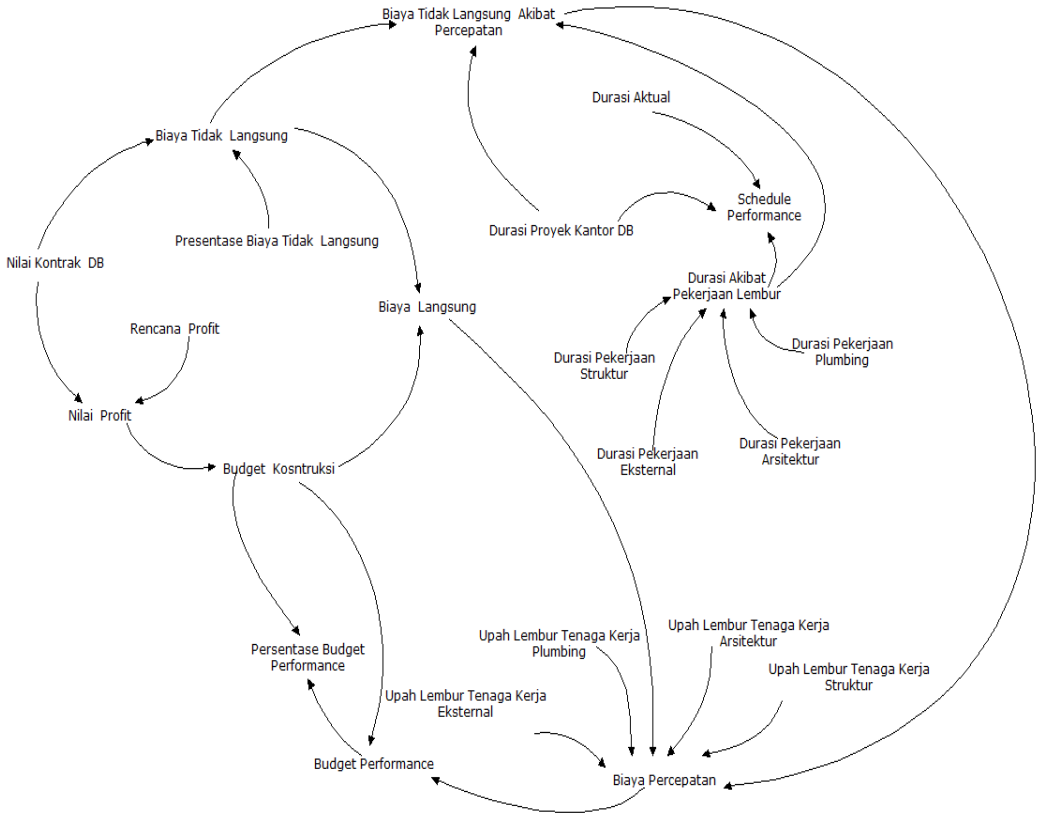

Figure 2. Causal Loop Diagram (CLD)

The causal loops of the system dynamic model of the design and build project for high-rise office buildings are formulated through shared thinking. This model represents overtime decision making in each job. The form of output from this model is in the form of time and cost estimates.

Stock and Flow Chart (SFD)

After the CLD was formed, the SFD was developed based on the caustic diagram as shown in Fig. 1. SFD describes the flow structure to build a mathematical model. Mathematical models are created by adding formulas and data to each variable. SFD was formed based on Project Duration Acceleration. In this model there are two levels of variables, namely Budget Performance and Schedule Performance. Profits are influenced by the construction budget and acceleration costs. The value of indirect costs per day will also be affected by the actual indirect costs, the actual duration, and the duration due to acceleration.

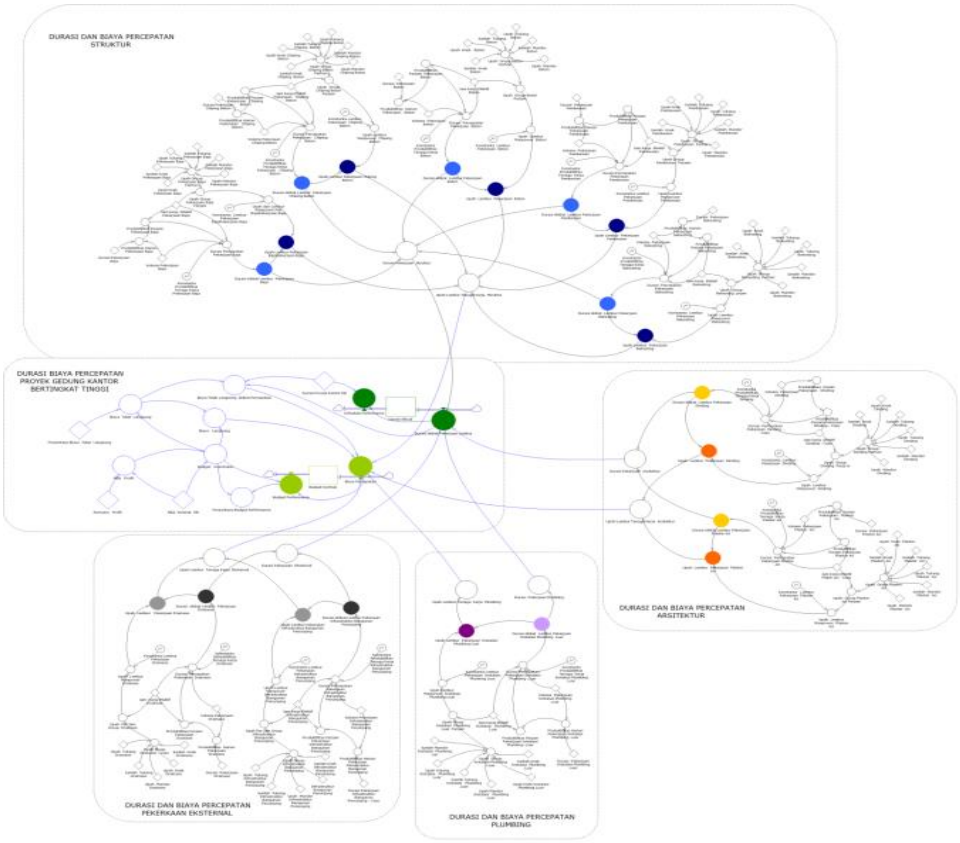

Figure 3. Project Duration Acceleration Scenario Model

All of these processes are simulated using the Stock and Flow Diagram (SFD) from Crasing calculations in each construction work activity as shown in Fig. 2. As mentioned earlier, Stock and Flow Diagrams are developed from mathematical models. The scenario proposed in this research was inspired by the research of Waliulu & Adi, 2021 which describes the use of a multi-objective optimization model and to demonstrate its ability to generate and visualize the optimal trade-off between breaking down costs and increasing profits and explaining project acceleration is one of the techniques commonly applied by contractors and engineers to overcome time over run. However, project acceleration can be controlled and lead to profitable results. For this purpose, historical data and micro-analysis of projects are required. The construction of the One Tower project also requires ways to improve project performance, which will directly affect the budgeting and planning process. The benefit of implementing this accelerated duration in the construction of the One Tower project is to increase contractor profits through a trade off between indirect cost savings and crashing costs.

The basic model is then developed into a scenario model by adding acceleration duration, indirect cost savings, and crash cost variables. In the scenario model, several new balancing loops and one reinforcing loop are formed. Changes in contingency costs will reduce the percentage of contingency costs that were originally planned. While profit changes, it will increase the percentage of expected profit. The acceleration duration variable directly affects the Schedule Performance Index (SPI), and if the SPI increases it will reduce the number of durations required to accelerate. Acceleration duration also indirectly affects contingency costs and profits by adding crash costs and increasing profits with indirect cost savings.

Verification and validation

The verification process is carried out to ensure the model is free from errors and the model is accurate and meets expectations. This process was carried out by means of the average comparison test and the average variance amplitude comparison test. the mean (E1) and the amplitude variance

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(E2). The maximum value of E1 is 5% and E2 is not more than 30%. This process is done by comparing simulated data with actual data. The results showed that each validated variable had a mean-variance below 5% and an error variance below 30%. Thus, the model formed meets the verification and validation requirements. The results of the validation of each variable show the average variance. mean (E1) = 4.19% and amplitude variance (E2) 4.34% so that the actual system can affect the increase in time and cost performance.

RESULT AND DISCUSSION

In making research scenarios, the results must have a systematic and precise analysis. By controlling project acceleration, it is expected to be able to increase project performance. Recommendation i with Dynamic System (SD) database modeling and ends with a scenario of the relationship between accelerated project duration, budget performance and crashing costs. This model analyzes the effect of duration acceleration on actual value components, based on direct and indirect cost components. From the scenario model, we can see the relationship between accelerated project duration, contractor incremental profits and the impact of crash costs on contractor profits and contingency costs and find appropriate innovative solutions to improve project performance and sensitivity.

Table 1. Of Project Duration Acceleration Scenario

Existing Scenario		**Pessimistic Scenario**		**Moderate Scenario**		**Optimist Scenario**	
Time (days)	Construction Costs (IDR)	Time (days)	Construction Costs (IDR)	Time (days)	Construction Costs (IDR)	Time (days)	Construction Costs (IDR)
594	223,556,544,228.51	526,56	219,745,893,461.79	423	214,404,168,232.02	352,37	210,762,889,471.01
Scenario Center							
Validation of project participants From the point of view of the project manager and the team		1 Hour Overtime Pessimistic Scenario The application of overtime is carried out with the consideration that the duration of the project tends to be sloping and labor productivity is classified as standard		3 Hour Overtime Moderate Scenario The application of overtime is carried out by considering the duration of the project which tends to be moderate and labor productivity is classified as standard		5 Hour Overtime Optimist Scenario The application of overtime is carried out with the consideration that the duration of the project tends to be tight and labor productivity is relatively fast	

CONCLUSION

This paper uses dynamic system modeling to analyze the root causes of problems and find appropriate solutions to improve project performance. Interviews and data observations were conducted to explore the processes that occur in the system. Making a Causal Loop Diagram (CLD) to describe the relationship between work activities in terms of budget and time, developing a Stock Flow Diagram (SFD) based on the budget performance sub-model. Validation and verification are also carried out on each stock and sub-model to ensure that the model matches the actual system. For the results obtained from this study, the increase in cost performance to contractor profits is 4.8% and project time efficiency is 37.0 8%. This research can be expanded by adding more variables or scenarios that can reduce costs and increase profits. This research can be used as a reference to help construction practitioners and academics whose research focuses on building acceleration

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