A Simulation Study of Duration-Budget Trade-Off in Home Renovation Project Management

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Abstract. This paper simulated home renovation project management with 15 work items to complete. All work items are depicted in a network diagram to help the project planner manage the house renovation project. CPM/PERT helps the project planner to determine the duration of work and the costs involved. CPM/PERT shows the period needed based on the critical path obtained is 40 days, with a cost requirement of IDR 89,750,000. The project crashing technique shortened the project's duration to 25 days, with an estimated total cost of IDR 112,100,000. The cost calculations for CPM/PERT and project crashing use the Activity Based Costing (ABC) method. This paper examines how to shortened duration impact the overall budget. Both the client and contractor can get an idea of how to complete the house renovation project and the cost requirements that accompany it.

1. Introduction
Discussing a project or business will always be related to management [1]. Management relates to planning, implementation, and supervision in a particular project (e.g., home renovation). Managing a home renovation project is different from building a house from scratch, including managing resources such as labor, materials, duration/length of time of completion, and the required costs [2]. Clearly, the main purpose of avoiding any losses and gain maximum benefits [3].

This paper used a case study from CV Hosnika Super Jaya’s house renovation project. They are a company with construction expertise, including home renovation. Since they handled some projects simultaneously, it is critically important to decide which project should be accomplished first to avoid swelling costs [4]. Obviously, completing projects on time is also necessary for company performance evaluation [5].

This present study discussed a home renovation project with a 45 m² building area on 236 m² land. The jobs include repairing damages due to prior rental and adding new rooms. The homeowner wished that the contractor (CV Hosnika Super Jaya) could fix the damages and used the vacant land for business’ purposes [6]. It is clear; the constructor needed the right method to manage this project on time within the appropriate budget [7].

This study used the Critical Path Method (CPM)/Project Evaluation and Review Technique (PERT), Project Crashing methods, and combined it with the Activity-Based Costing (ABC) method to solve this challenge. CPM/PERT are management techniques [8][9]. Some studies that applied CPM/PERT methods, including project management information system, ship development project management [10], automotive engine repair analysis [11], and planning in the industry [12]. Further, the results of
those methods will be calculated using the Project Crashing method [13]. This calculation method tried to accelerate project length duration by increasing cost [14]. As a result, the manager could predict any additional cost because of time acceleration. In more detail, Project Crashing used ABC as its formula in doing a calculation. These calculations are considered raw materials and all of the activity stages. Therefore, this study’s main aim is to examine project duration, the possibility of time acceleration, and incurred cost as its consequences. This study can be used as a reference for contractors and or consumers who need a home renovation in the future.

2. Cost Calculation Activity Based Costing (ABC)
In each project, determining the project’s detailed cost is essential [15] to accommodate this need, ABC is one option since it calculates cost and activities identification [16]. Most companies used ABC methods to reduce costs or ineffective activities. As the aforementioned, ABC has been known widely as a calculation method that combines the price of raw materials and the cost of each production stage activity. By adding both components together, the constructor and customer can determine a particular project’s total price. This method is also useful for re-analyzing the effectiveness of each raw material and activity and eliminating any raw materials or activities if necessary. [17]

This method has been applied in various businesses, such as manufacturing, buying and selling activities, and service companies. The advantages of ABC vary: (1) assisting companies in decision making, (2) determining selling price, and (3) helping management in improving cost analysis. Generally, companies need to make decisions across subjects such as materials’ purchase, marketing price, and labor cost. This method might help decide the products’ selling price; thus, companies can compete by reducing the risk of losses and offering their products’ best quality. In turn, companies can re-elect and re-engineering production processes using other raw materials in the future.

ABC’s formula can be written as Equation 1.

$$Z = \sum_{i=1}^{m} \sum_{j=1}^{n} (a_i x_i + b_j y_j)$$

where Z is the principal value of production, a is the number of x raw material, and b is the number of y activity. Z is a value calculation measured in IDR units.

3. Determination Of House Renovation Critical Project Using CPM / PERT
CPM/PERT uses network technique as a popular method in project analysis. Technically, CPM/PERT uses nodes and lines to describe works’ list, works duration, and works order. The main differences between CPM and PERT in predicting time estimation. CPM determines critical paths using nodes every time, whereas PERT describes activities using lines with arrows between two nodes [18]. Figure 1 shows a combination of CPM/PERT techniques. CPM/PERT method helps in examining risk analysis during project completion [19] [20]. Therefore, using CPM/PERT can optimize project construction’s schedule [21] and minimize the required cost [22].

![Figure 1. Typical CPM/PERT graph](image)

4. Calculation Of Project Duration Acceleration Duration Using Project Crashing
Project crashing is a method for calculating the shortened duration of work by adding the required cost [23]. The shorter length of work happens due to labor and or adjustments of raw materials and quality techniques. For instance, in a home renovation project, you can use additional drugs/hardener raw materials to speed the drying process of cement up. Ceramic installation can use this method also. More detail, initially, ceramics installation was completed by two people in four working days. It can be
shortened to two working days by increasing three to four workers. As a result, it might impact the
general project’s cost. Therefore, it is important to determine the project activity fixed cost based on the
ABC method to calculate [24].

5. Methodology
To find project fixed cost, we used steps follows:

Figure 2. Research methodology

1. Determine the list of jobs that must be completed along with work duration and the required costs.
   Calculate the amount of cost using the ABC method.
2. Arrange works’ order.
3. Describe the works’ sequences in a network diagram.
4. Calculate the critical path.
5. Analyze the calculation.
6. Calculate the possibility of a shorter work period and the amount of required cost and do critical path calculation at step four at the same time.
7. Analyze the calculation results in stage sixth.
8. Compare the calculation results of step fifth and seventh.

6. Result and Discussion
This study used the CV Hosnika Super Jaya home renovation project as its case study. Figure 3 describes the initial client house’s and Figure 4 shows the plan’s blueprints. A work set includes adding a room in the back, changing the bathroom’s location, making a kitchen, and creating a business room in the front.

![Initial client house blueprint](image)

**Figure 3.** Initial client’s house blueprint
Figure 4. The next client’s house blueprint

For accomplishing this project, CV Hosnika Super Jaya makes a job list follows:
1. For adding a new room at the back, mow down the old walls and build a new wall as a room divider. Also, install the roof and tiles for the new room.
2. For changing the bathroom’s location, it is necessary to mow down the old bathroom first. The new bathroom will be located in the back of the house. This new bathroom will be dry and does not need a water reservoir.
3. For the new kitchen, the dimensions are 3m x 2m. This kitchen will be located next to the new bathroom. The client wants to have easy access to both rooms. Thus, the old wall at the back should be mowed down first. Besides, this kitchen will be equipped with a kitchen set.
4. Adding a business room at the front requires additional walls and a selected interior, which will be appropriate for this purpose. The client chooses a harmonica model as its door.

Moreover, for each of the work items, the required cost will be calculated using the ABC method. For example, for adding new room space, job details, and costs’ component follow:
1. Service fees to move down the old wall (2 labors x 4 work days x IDR 125,000) = IDR 1,000,000
2. Cost of materials and services for making foundation (standard room foundation)
3. Cost of materials and services for building walls (standard walls using red bricks)
4. Costs for roofing materials and services (standard roof’s frames using galvalume)
5. Cost of materials and room for painting services
6. Material costs and room electrical installation services

For points 2-6, the unit calculation is based on the room area. For instance, adding a 3m x 3m room needs IDR 1,500,000 per m² during seven days’ work. Thus, in total, it needs IDR 13,500,000. We repeated this calculation method for the other three works. Again, this calculation considers the required cost, completed day estimation, and the number of labor.

Based on the ABC method calculation, initially, this house renovation only consisted of three work items. Then, it can be detailed into 15 work items follow:
1. Break down the walls in the back of the building used for a new room, kitchen, and bathroom. The expected work time is four days by two laborers. Thus, the estimated cost is IDR 1,000,000
2. Creating a room that will be used as a place of business by utilizing an empty area in front of the house. The expected room’s area is approximately 15 m². The time needed to complete this work is about seven days. The estimated cost for seven days’ completion is IDR 1,500,000/m². Thus, the total required cost for business space is IDR 22,500,000
3. Add a new room in the back of the house. The room size is 9 m². The process takes seven days. The estimated cost needed is IDR 13,500,000
4. Work on tile installation for all new rooms and replace old tiles. The length of work is eight days, with a total cost of IDR 2,000,000.
5. Build a new kitchen with a total area of 6 m². It is estimated that three days will be needed. The total cost for this kitchen is IDR 5,000,000.
6. The location of the new bathroom is next to the kitchen. The area of the bathroom is 3 m², with an estimated cost of IDR 4,500,000. This work includes the installation of drains and toilets. The estimated working time is five days.
7. Replacing old ceramic for creating new nuance to the new rooms. The expected duration of work is three days. The total needed cost is IDR 300,000.
8. Work on the installation of eight doors and windows in three days. The required total cost, including door and window materials, is IDR 15,000,000.
9. New ceramic installation for 70 m² area. The estimated duration is seven days, with IDR 130,000 for each m². Thus, the total cost is IDR 9,000,000.
10. Two days of fence installation needs IDR 5,000,000.
11. Three days canopy roof installation for approximately 12 m² with the estimated cost is IDR 6,000,000.
12. Painting works which will be completed within four days needs IDR 4,000,000
13. Work on painting the outside area, which requires two days and a total cost of IDR 1,000,000.
14. The fence painting takes one day, and it cost IDR 500,000
15. Final inspection as a quality control needs three days with a total cost of IDR 450,000.

After a detailed job list has been made, described the work’s sequence in the form of a network diagram, as shown in Figure 5.

**Figure 5.** Network chart

The numbers in the node indicate the order of the job list. The amount listed above the node means the duration/length of time needed to complete the work. Table 1 depicted 32 lines of project completion.
It is called the fastest start time, which is symbolized by \( ES \) (early start time). After determining the critical path, we design activities’ schedule for counting network in more detail. It can be calculated by adding completed time accomplishment of previous activity within a network. We can also decide the fastest starting time for a specific activity in the starting time of a particular activity added by its duration. The calculation formulas for \( ES \) and \( EF \) values are shown in Equation 2 and Equation 3.

\[
ES = \text{Maximum (previous } EF \text{ activity)} \tag{2}
\]

\[
EF = ES + t \tag{3}
\]

Table 1 shows that path E has the longest nodes path within 40 days of completion. Therefore, E is called the critical path. After determining the critical path, we design activities’ schedule for counting the fastest time completion for each activity. For example, the fastest time to start node 4 is the 11th day. It is called the fastest start time, which is symbolized by \( ES \) (early start time).

In determining \( ES \) value, we connect and calculate the first node to the final nodes representing each activity within a network. We can also decide the fastest starting time for a specific activity in the network in more detail. It can be calculated by adding completed time accomplishment of previous activities, except for the initial node. The fastest finish time \( (EF \) or early finish) is the previous fastest starting time of a particular activity added by its duration. The calculation formulas for \( ES \) and \( EF \) values are shown in Equation 2 and Equation 3.

\[
ES = \text{Maximum (previous } EF \text{ activity)} \tag{2}
\]

\[
EF = ES + t \tag{3}
\]

We provide some examples using path E as the critical path, for example, activity 1. Since it is the first activity, it means the \( ES \) is zero. This activity needs four days. Thus, the \( EF \) is equal to four days, as shown by this formula.

\[
ES = 0
\]
EF = ES + t = 0 + 4 = 4 days

Another example is activity 3. From path E, we can see that the link connects activity 1 to activity 3
nodes; thus, for this calculation, activity 1 is the EF. Because activity 3 needs seven days, it is shown
below when we plug into the formula.

ES = Maximum (EF) = 4 days

EF = ES + t = 4 + 7 = 11 days

We performed the formula for all nodes to calculate the ES and EF values. Simultaneously, this
calculation also requires the latest starting time (LS) and the last finishing time (LF). The latest starting
time is the time duration of the latest activity, which the beginning of this activity will not cause any
delay and exceed critical path time. In more detail, the LF calculation uses a backward pass. LF starts
from the latest job’s list, which is node 15, and it moves backward. Equation 4 and Equation 5 explain
LS and LF formulas, followed by two examples. Table 2 describes the complete result for each node.

\[
LS = LF - t \quad (4)
\]

\[
LF = \text{Minimum (LS activity that follows)} \quad (5)
\]

Table 2. Result of ES, LS, EF, and LF

| Activity | Activity time | Early Start | Early Finish | Late Start | Late Finish | Slack |
|----------|---------------|-------------|--------------|------------|-------------|-------|
| 1        | 4             | 4           | 4            | 0          | 4           | 0     |
| 2        | 7             | 0           | 7            | 4          | 11          | 4     |
| 3        | 7             | 4           | 11           | 4          | 11          | 0     |
| 4        | 8             | 11          | 19           | 11         | 19          | 0     |
| 5        | 3             | 19          | 22           | 21         | 24          | 2     |
| 6        | 5             | 19          | 24           | 19         | 24          | 0     |
| 7        | 3             | 19          | 22           | 21         | 24          | 2     |
| 8        | 3             | 19          | 22           | 21         | 24          | 2     |
| 9        | 7             | 24          | 31           | 24         | 31          | 0     |
| 10       | 2             | 24          | 26           | 34         | 36          | 10    |
| 11       | 3             | 24          | 27           | 34         | 37          | 10    |
| 12       | 4             | 31          | 35           | 31         | 35          | 0     |
| 13       | 2             | 35          | 37           | 35         | 37          | 0     |
| 14       | 1             | 26          | 27           | 36         | 37          | 10    |
| 15       | 3             | 37          | 40           | 37         | 40          | 0     |

It is clearly seen, some activities have zero as its slack values. It refers to the critical path. Therefore,
those activities should be started as scheduled and cannot be postponed in the middle. Otherwise, it
might impact the overall project construction. Conversely, if the list of activities does not show zero
slack value, the constructor can further delay its execution without significant problems. Equation 6 and
Equation 7 depicts the slack value (S) formula.

\[
S = LS - ES \quad (6)
\]

\[
S = LF - EF \quad (7)
\]
Table 2 shows that the S value of node 2 is 4 days. It means this activity can be finished until a four days delay without affecting the overall time of the house renovation project. A similar explanation applies for activity 2, 5, 7, 8, 10, 11, and 14 with different numbers of delayed days.

Another benefit of using CPM / PERT, we can also find how much the amount of crashing. Crashing is shortening project work time by adding cost components. The project crashing method uses the ABC calculation method. Types of additional costs cover labors, materials, and changing certain raw material types. This calculation is intended to accelerate the duration of completion of work items.

Table 3. Data for project crashing

| Activity | Activity time | Crash time | Normal Cost | Crash Cost |
|----------|---------------|------------|-------------|------------|
| 1        | 4             | 2          | 1           | 1.5        |
| 2        | 7             | 5          | 22.5        | 25         |
| 3        | 7             | 5          | 13.5        | 16         |
| 4        | 8             | 4          | 2           | 3          |
| 5        | 3             | 2          | 5           | 7          |
| 6        | 5             | 3          | 4.5         | 7          |
| 7        | 3             | 2          | .3          | .8         |
| 8        | 3             | 2          | 15          | 15.5       |
| 9        | 7             | 5          | 9           | 9.5        |
| 10       | 2             | 1          | 5           | 5.5        |
| 11       | 3             | 2          | 6           | 6.5        |
| 12       | 4             | 3          | 4           | 4.5        |
| 13       | 2             | 1          | 1           | 1.5        |
| 14       | 1             | .5         | .5          | 1          |
| 15       | 3             | 2          | .45         | .6         |

Table 3 shows the acceleration of project time and the required cost for each node. For example, the original length time duration for activity 1 is four days with IDR 1,000,000. Activity 1 can be shortened to two days with an additional cost of 1,500,000. In the crash, it is important to note that we must pay attention to the critical path (path E), which connects activities 1 - 3 - 4 - 6 - 9 - 12 - 13-15. Using POM QM version 5.3, we obtained the following, as shown in Table 4.

Table 4 depicts the project's initial duration is 40 days and can be reduced to 25 days. The total required cost by shortening the time duration is IDR 112,100,000 compared to the initial cost without crashing calculation is IDR 89,750,000.

Table 4. Project crashing result

| Activity | Normal time | Crash time | Normal Cost | Crash Cost | Crash cost/pd | Crash by | Crashing cost |
|----------|-------------|------------|-------------|------------|---------------|----------|--------------|
| Project  | 40          | 25         | 1           | 1.5        | .25           | 2        | .5           |
| 1        | 4           | 2          | 22.5        | 25         | 1.25          | 2        | 0            |
| 2        | 7           | 5          | 13.5        | 16         | 1.25          | 2        | 2.5          |
| 3        | 7           | 5          | 2           | 3          | .25           | 4        | 1            |
| 4        | 8           | 4          | 5           | 7          | 1.25          | 2        | 2.5          |
| 5        | 3           | 2          | 4.5         | 7          | 1.25          | 2        | 2.5          |
| 6        | 5           | 3          | .3          | .8         | .5            | 0        | 0            |
| 7        | 3           | 2          | 15          | 15.5       | .5            | 0        | 0            |
| 8        | 3           | 2          | 9           | 9.5        | .25           | 2        | .5           |
| 9        | 7           | 5          | 5           | 5.5        | .5            | 0        | 0            |
| 10       | 2           | 1          | 6           | 6.5        | .5            | 0        | 0            |
| 11       | 3           | 2          | 4           | 4.5        | .5            | 1        | .5           |
| 12       | 4           | 3          |             |            |               |          |              |
The calculation results show a trade-off between the duration and cost requirements while paying attention to the house renovation project's critical path. It is important to note that work on home renovation projects can be done sequentially following the process stages. Both the developer and the client could have alternatives on how to complete a home renovation project, lower cost with longer time duration, or higher cost with shorter time accomplishment. Thus, both client and CV Hosnika Super Jaya can agree on how to complete the house renovation project.

7. Conclusion

Project management by utilizing CPM/PERT techniques helps project managers to plan project completion better. CPM/PERT supports the project planner to calculate the duration/length of work for a project based on activities in the critical path. The critical path is the longest in the network diagram to count the minimum time needed to complete the project. In this case study, the selected critical path is activity 1 - 3 - 4 - 6 - 9 - 12 - 13-15, with a work duration of 40 days. CPM/PERT also helps project planners determine which activities can be delayed without interfering with overall project completion time, activities 2, 5, 7, 8, 10, 11, and 14.

Crashing calculation provides an overview for project planners to shorter work completion projects with necessary additional costs. Originally the work period was 40 days, shortened to 25 days with an estimated total cost of IDR 112,100,000 from IDR 89,750,000 initially.

This kind of project calculation method is urgently needed, both by contractors and consumers. In the future, other project management calculation methods that are deemed more effective can be used so that both contractors and consumers have a more varied alternative calculation method.

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