The implementation of non-unit-based scheduling method in a housing project

Kevin Natanael Christiawan*, Onnyxiforus Gondokusumo  
* Student of Civil Engineering Master Program, Faculty of Engineering  
Universitas Tarumanagara, Jakarta 11440, Indonesia  
mts@untar.ac.id, kevin.327182010@stu.untar.ac.id

Abstract. Of the various types of construction projects, contractors often encounter repetitive projects. Many methods have been used for scheduling repetitive projects, but most repetitive scheduling methods have the basis that they are composed of many identical production units. Scheduling repetitive projects using unit-based methods has several constraints such as modeling and applying them to construction projects requiring simplification of repetitive activities to have a single duration and in a fixed production sequence. Therefore, a non-unit-based scheduling method is developed. In this analysis, the project data was obtained from a housing project. Based on the data, an analysis was conducted to look for the effect of changes in the factors used in the non-unit-based scheduling method on the final duration of the project. From the analysis it was found that the factors used in the non-unit-based scheduling method such as duration, priority order of activities, number of resource groups, and relationships between activities greatly influenced the final duration of the project.

1. Introduction

Scheduling is related to the order and time of activities in a particular production process [1]. A repetitive construction project requires a project scheduling method that is able to accommodate continuous and well-scheduled resource needs without an obstacle [2], [3], [4]. Traditional scheduling methods, such as barchart are generally considered as less effective for the planning of repetitive projects, due to their inability to maintain resource work continuity [5]. Many methods have been used to schedule repetitive projects, although each of these methods was developed to meet their own specific goals, they are basically the same [6]. However, most repetitive scheduling methods, such as line of balance, have the basis that they consist of many identical production units. This somewhat limits the applicability of the method. Based on these needs, this study tries to find whether non-unit-based scheduling can be applied for repetitive project scheduling. To achieve that, in this study an analysis was conducted to look for the effect of changes in the factors used in the non-unit-based scheduling method on the final duration of the project. However, this study does not consider the cost aspect because non-unit-based scheduling only considers the total duration of the project and has not included other objectives that might change the optimal solution [7]. Figure 1 shows line of balance and non-unit-based chart.
Figure 1. Line of balance and non-unit-based chart

2. Method and data

2.1. Data acquisition

This study used scheduling data from the housing project in Bekasi, West Java. The project consists of one type of house with a land area of 66 m², a building area of 33 m² and only has one floor. In this project there are 48 housing units and 16 resource groups.

Table 1. Data from the housing project

| No. | Activity             | Successor | Relationship  | Duration (days) |
|-----|----------------------|-----------|---------------|-----------------|
| 1   | Preparation          | 2         | Finish to Start | 3               |
| 2   | Foundation           | 3,4       | Finish to Start | 14              |
| 3   | Column               | 5,8       | Finish to Start | 10              |
| 4   | Plumbing             | 9         | Finish to Start | 5               |
| 5   | Wall 1               | 6,7       | Finish to Start | 5               |
| 6   | Wall plaster         | 12        | Finish to Start | 7               |
| 7   | Wall 2               | 10        | Finish to Start | 5               |
| 8   | Floor covering       | 11        | Finish to Start | 9               |
| 9   | Sanitation           | 11        | Finish to Start | 5               |
| 10  | Roof                 | 12        | Finish to Start | 13              |
| 11  | Door and window      | 15        | Finish to Start | 2               |
| 12  | Mechanical Electrical 1 | 13,14  | Finish to Start | 3               |
| 13  | Ceiling              | 15        | Finish to Start | 7               |
| 14  | Mechanical Electrical 2 | 15  | Finish to Start | 2               |
| 15  | Paint                | -         | -             | 10              |

Table 1 shows data collected in the form of a list of activities carried out for a house, the duration of each activity and the type of relationship between activities.

2.2. Method

Data obtained from the project will be processed by the non-unit-based scheduling method so that the duration of the project is obtained and then the results are presented in chart form. After that, various scheduling scenarios are made by changing factors in non-unit-based scheduling. Then the results of the duration of the projects are compared with each other. The analysis process carried out by the non-unit-based scheduling method consists of several steps.

2.2.1. Identify activity groups

Instead of repetitive production units, non-unit-based scheduling identifies and uses groups of repetitive activities. Therefore, the first step is to identify activity groups. At this step, the types of activities in the project will be divided into groups of activities according to their functional objectives. Non-repetitive activities can be included in separate activity groups.

2.2.2. Formulate the resource chain

At this step, the activities contained in each activity group are determined in priority. Then determined the assignment of resource groups in each activity group. After the assignment of resources and priorities for activities are determined, a resource chain for each type of resource can then be made.

2.2.3. Conduct resource chain scheduling

At this step, the resource chain from the first activity group is made a baseline schedule for start and finish time based on the duration of the activity. The baseline schedule for the resource chain of the first group of activities can immediately become the project schedule because it does not have...
predecessors. Then for the next activity group resource chain, each activity in the resource chain is calculated at the earliest possible start time for each activity based on the final completion time of the predecessor activity. If in one activity there is more than one predecessor activity, then the largest finish time is chosen. After the earliest start time of each activity in the resource chain is obtained, it is then subtracted by the start time of the activity from the schedule baseline to get the earliest possible start time. Then from the earliest possible start time, the largest is chosen to be the start time of the resource chain so that it can get the start and finish time of the project schedule for the resource chain. Next, the project schedule starts and finish time for each resource chain is calculated until the overall project schedule is obtained.

3. Results and discussion

3.1. Scheduling result from housing project data

From the project data it is known that there are 48 units and 16 resource groups, so one resource group works in 3 housing units. For example, group 1 works in unit 1-unit 17-unit 33, group 2 works in unit 2-unit 18-unit 34 and so on. The result of project duration obtained by non-unit-based scheduling is 128 days.

3.2. Scheduling result from various scheduling scenarios

Various scheduling scenarios are made by changing factors in non-unit-based scheduling. In this scenarios, the factors that are changed in the non-unit-based scheduling method are the duration of the activity, the order of priority of activities, the number of group resources, and the relationship between activities.

3.2.1. Activity duration difference scenario

In the activity duration difference scenario, activities on a house project that had the same duration for all houses will be made into three types of houses with different duration of activities for each type.

| No. | Activity                  | Successor | Relationship | Duration (days) |
|-----|---------------------------|-----------|--------------|----------------|
|     |                           |           |              | Type 1 | Type 2 | Type 3 |
| 1   | Preparation               | 2         | Finish to Start | 3      | 3      | 4      |
| 2   | Foundation                | 3,4       | Finish to Start | 14     | 10     | 12     |
| 3   | Column                    | 5,8       | Finish to Start | 10     | 12     | 10     |
| 4   | Plumbing                  | 9         | Finish to Start | 5      | 6      | 4      |
| 5   | Wall 1                    | 6,7       | Finish to Start | 5      | 6      | 5      |
| 6   | Wall plaster              | 12        | Finish to Start | 7      | 9      | 8      |
| 7   | Wall 2                    | 10        | Finish to Start | 5      | 6      | 6      |
| 8   | Floor covering            | 11        | Finish to Start | 9      | 10     | 7      |
| 9   | Sanitation                | 11        | Finish to Start | 5      | 7      | 4      |
| 10  | Roof                      | 12        | Finish to Start | 13     | 8      | 15     |
| 11  | Door and window           | 15        | Finish to Start | 2      | 3      | 2      |
| 12  | Mechanical Electrical 1   | 13,14     | Finish to Start | 3      | 4      | 3      |
| 13  | Ceiling                   | 15        | Finish to Start | 7      | 9      | 5      |
| 14  | Mechanical Electrical 2   | 15        | Finish to Start | 2      | 3      | 3      |
| 15  | Paint                     | -         | -             | 10     | 12     | 10     |

Table 2 shows each activity has 3 types of duration, so each type consists of 16 units with a total of 48 housing units. Type 1 is unit 1-16, type 2 is unit 17-32, and type 3 is unit 33-48, so each group works on 3 units with different types such as group 1 works in unit 1 (type 1)-unit 17 (type 2)-unit 33 (type 3) and so on. After processing data with different duration of activities for each type, then the results obtained is 120 days. The differences in results with projects with the same duration of activities can
be caused by changes in relations with predecessor activities. For example, the activity will be connected in the first unit with its predecessor because its duration is greater than its predecessor. However, it will change to be connected in the last unit if the duration changes are smaller than its predecessor. This is because the progress of the work of the successor may not precede the predecessor [8].

3.2.2. Change of order priority of activity scenario
In the change of order priority of activity scenario, three types of units are still used with different duration of activities for each type. However, the order of priorities in the previous scenario was changed in order to get a different scheduling. In previous scenario, the priority order of activities is priority order 1 (type 1-type 2-type 3). But in this scenario the priority order of activities is priority order 2 (type 3-type 2-type 1) and priority order 3 (type 2-type 1-type 3). Each group still works on 3 units with different types but with different order such as for priority order 2, group 1 works in unit 33 (type 3)-unit 17 (type 2)-unit 1 (type 1) and so on. For priority order 3, group 1 works in unit 17 (type 2)-unit 1 (type 1)-unit 33 (type 3) and so on. After processing data with three different priority sequences, different duration results are obtained. Projects in priority order 2 have a duration of 119 days and projects in priority order 3 has a result of 124 days. The difference in scheduling results between the three priority orders can be caused by changes in relations with predecessor activities and differences in the duration of predecessor activities.

3.2.3. Change in number of resource groups scenario
In the change in number of resource groups scenario, only the number of resource groups will be change and activity duration remains the same for all types in the project. Changes in the number of resource groups often occur in construction projects [9]. The number of resource groups will be reduced to half from 16 resource groups to 8 resource groups. So in this scenario, one resource group works on 6 housing units, for example group 1 works in unit 1-unit 9-unit 17-unit 25-unit 33-unit 41 and so on. After processing data, the results obtained with 8 groups were not doubled compared with the results with 16 groups. The results of the project with the number of resource groups 8 groups obtained 215 days. The difference in scheduling results can be caused by the addition of the fastest start time of the predecessor activity at the activity schedule baseline for calculating the project schedule.

3.2.4. Change in relationships between activities scenario
In the scenario of change in relationships between activities, some relationships between activities are changed by combining activities that are divided in duration. The change in relationships is because in conventional networks the finish to start relationships are most commonly used [10].

Table 3. Change in relationships between activities scenario
Table 3 shows that activity wall 1 and 2 are combined into activity wall and the relationship with wall plaster becomes start to start with lag equal to the duration of wall 1, as well as mechanical activities 1 and 2 which are combined into mechanical electrical activities and the relationship with ceiling becomes start to start with a lag of the duration of mechanical mechanical activity 1. Figure 2 shows network modification in changes in relationships between activities scenario.

| No. | Activity          | Successor | Relationship     | Duration (days) |
|-----|-------------------|-----------|------------------|-----------------|
| 1   | Preparation       | 2         | Finish to Start  | 3               |
| 2   | Foundation        | 3,4       | Finish to Start  | 14              |
| 3   | Column            | 5,7       | Finish to Start  | 10              |
| 4   | Plumbing          | 8         | Finish to Start  | 5               |
| 5   | Wall              | 6         | Start to Start+5 | 10              |
| 6   | Wall plaster      | 11        | Finish to Start  | 7               |
| 7   | Floor covering    | 10        | Finish to Start  | 9               |
| 8   | Sanitation        | 10        | Finish to Start  | 5               |
| 9   | Roof              | 11        | Finish to Start  | 13              |
| 10  | Door and window   | 13        | Finish to Start  | 2               |
| 11  | Mechanical Electrical | 12   | Start to Start+3 | 5               |
|     |                   | 13        | Finish to Start  |                 |
| 12  | Ceiling           | 15        | Finish to Start  | 7               |
| 13  | Paint             | -         | -                | 10              |

Figure 2. Changes in relationships between activities scenario

After processing the data with the relationship between the activities of finish to start (FS) and start to start (SS), the results obtained are 114 days in the project with the start to start relationship. The difference in scheduling results will be explained by the illustrations in figure 2. The differences in scheduling results can be caused by:

- Duration of activity A. Breaking the duration of the activity can make activity A seem to be two separate activities and there can be a time lag between the activity. Figure 3 shows effect of duration of activity A on the result.
In Figure 3a, the duration of activity A1 is greater than activity A2, causing a time lag in the first unit. The time lag makes the results of scheduling in FS longer than SS. Whereas in Figure 3b, the duration of activity A1 is smaller than A2 so that the time lag does not appear in the first unit. Due to the absence of time lag in the first unit, the scheduling results are the same as the FS with SS because the duration of A at SS is equal to the total duration of activities A1 and A2 at FS.

- Duration of activity B. If activity B is greater than activity A2, what affects the outcome of the project duration is the duration of activity B and vice versa.
- The duration of predecessor activities A and successor activities A and B.

4. Conclusion
Based on the results of the implementation that has been done from the housing project data, it is proved that non-unit-based scheduling method can accommodate the scheduling of the repetitive project and obtain scheduling results closer to the situation in the project. From the analysis it is concluded that the factors used in the non-unit-based scheduling method such as duration, priority order of activities, number of resource groups, and relationships between activities greatly influenced the final duration of the project. Furthermore, some constraints on scheduling with line of balance can be facilitated by non-unit-based methods so it makes non-unit-based scheduling more flexible than line of balance. Then on changes in the relationships between activities, there are several key factors that can affect the outcome of the final project duration either longer or shorter.

5. References
[1] Uher T E 2003 Programming and Scheduling Techniques (Sydney: University of New South Wales Press Ltd)
[2] Harris R B and Ioannou P G 1998 Repetitive Scheduling Method (Michigan: Civil and Environmental Engineering Department–University of Michigan)
[3] El-Rayes K 2001 Object-oriented model for repetitive construction scheduling J. Constr. Eng. Manage. 127(3) 199–205
[4] Hyari K and El-Rayes K 2006 Optimal planning and scheduling for repetitive construction projects J. Constr. Eng. Manage. 22(1) 11–9
[5] Huang R and Sun K 2006 Non-unit-based planning and scheduling of repetitive construction projects J. Constr. Eng. Manage. 132(6) 585–97

[6] Zhang L and Jianxun Q 2012 Controlling path and controlling segment analysis in repetitive scheduling method J. Constr. Eng. Manage. 138(11) 1341–45

[7] Eid M S 2012 Multi objective non-unit-based repetitive activities projects scheduling using genetic algorithms Thesis (Arab Academy for Science & Technology and Maritime Transport)

[8] Hinze W J 2008 Construction Planning and Scheduling 10th Edition (New Jersey: Prentice Hall)

[9] Assaf S A and Al-Hejji S 2006 Causes of delay in large construction projects Int. J. of Proj. Manage. 24(4) 349–57

[10] Lu M and Lam H 2009 Transform schemes applied on non-finish-to-start logical relationships in project network diagrams J. Constr. Eng. Manage. 135(9) 863–73