A comparative study on bridge road works methods for flood tide management in Agats-Suator project

H Dermawan¹, W Palamba² and E Sebayang²

¹Civil Engineering Department, Faculty of Computer Science and Engineering, ²Universitas Kristen Krida Wacana

Corresponding author: hans.dermawan@ukrida.ac.id

Abstract. Currently, flood tide affects the accessibility of Agats-Suator Bridge Road. Therefore, local governments are making efforts to improve its infrastructure, one of which is in the bridge road construction previously used wood conventionally replaced with better concrete. This study examines the Agats-Suator Bridge Road Project, Asmat, Papua that compares the precast concrete system and conventional concrete system for flood tide management, in which workers were employed and materials were purchased from Surabaya. The purpose of this research is to calculate efficient scheduling conditions with a limited workforce on conventional and precast concrete implementation systems. The research method used in this research is a non-experimental quantitative method with comparative studies. Human resource allocation makes the workers scheduling more efficient by applying the principle of limited resource allocation. The research results show that the precast concrete system reach ideal conditions at rmax = 30 people with 18 weeks duration. Meanwhile, conventional concrete systems reaches ideal conditions at rmax = 89 people with 22 weeks duration. The result of resource allocation suggests that implementing a precast concrete system is more effective than implementing a conventional concrete system. The results of this study also function as a reference in selecting the concrete construction implementation systems for flood tide management in Agats-Suator Bridge Road Project.

1. Introduction

Worker, material, and equipment planning are parts of resource planning. It includes planning the workforce, material, and scheduling equipment procurement for a project. The final results of this plan will be used as a basis for controlling the workers, materials, and tools during the project implementation, and for that reason, it is expected to quickly detect any deviations from the plan earlier [1].

In implementing the project, the determining factor for its success is the workforce. The types and activities of projects change rapidly throughout the cycle, and therefore the provision of skills and expertise must keep pace with the changing demands of the ongoing activities. Considering this reality, a comprehensive and detailed workforce planning includes the type and when the workforce is needed [2].

Currently, Agast-Suator often has accessibility problems as a result of the flood tide and heavy rainfall. Therefore, local governments are making efforts to improve its infrastructure, one of which is in the bridge road construction that previously used wood materials conventionally replaced with better concrete bridge roads. Resource management will be processed in the workforce scheduling to
determine the appropriate implementation system for the Agats-Suater Bridge road construction. The inefficient scheduling model seen in the graph shows a fluctuating number of workers or the number changes significantly.

The figure below is a histogram displaying the number of construction workforce employed in two implementation methods: local cast / conventional concrete and precast concrete. The figure shows uneven or fluctuating data on the number of workers during the project implementation, in which the average fluctuation is 84.53% in the precast concrete system and 110.8% in the conventional concrete system. The location and nature of construction in Papua do not allow fluctuating labor distribution or even a large number of labor arrivals from other islands. Therefore, it is necessary to arrange an efficient workforce composition to keep project sustainability as planned. Agats-Suater Bridge Road project is located in Asmat District, Papua Province. The flood tide constrains the only available road access, in which it was made of wood and only accessible for pedestrians and motor vehicles. The construction of this bridge road connects the Suater district with Agats (the capital of Asmat Regency). The purpose of this research is to calculate efficient scheduling conditions with a limited amount of workforce on conventional and precast concrete implementation systems. The results of the study function as a reference for selecting concrete construction implementation systems.

![Figure 1. The Number of workers on precast concrete system](image1)

![Figure 2. The Number of workers on conventional concrete system](image2)

The project management flow includes determining the objectives of implementation, planning, resource scheduling (staffing), making workflows (directing), the supervision process (supervising), and work control methods. According to Novitasari, proper project resource management for planners is to pay attention to the following [3]:

- Project scheduling, budgeting, resource management (manpower planning). Project scheduling and progress is seen in the S curve. The project cost budget is seen in the project document. Resource settings are scheduled for each resource according to field needs;
- Control of construction projects (controlling)
1.1. Workforce management

The problem of resource leveling arises when there are sufficient resources available and need to reduce fluctuations in resource use patterns [4]. In a project, workers are the essential resource. A good workforce schedule is a schedule with activities arranged in an ideal gradual pattern with the following figures [5,6]:

![Ideal charts for project workforce procurement schedules.](image1)

Ideal workforce scheduling can be done by modifying the planner's data scheduling and the progress of the construction project implementation. Workforce scheduling shows a pattern that states the relationship between the amount of the duration of the project and the number of workers, and it depends on each other. The ideal scheduling pattern shows the value of regression analysis that is close to 1 or equal to 1. The scheduling pattern with the difference in the number of workers, which includes the ideal category, is the minimum amount of fluctuation. Fluctuations that are kept to a minimum value, tend to have normal distribution curve-shaped patterns. This curve is shown by the pattern at the beginning of the work duration, the number of workers is small, then the number increases significantly, and at the end of the duration the number decreases [7].
1.2. Resource levelling

Resource leveling is a project scheduling method applied to avoid sharp fluctuations in resource requirements on a project. This is done by ensuring equitable distribution of available resources to avoid excessive available resources which can result in resources not being utilized accordingly and it might cause project financial loss [7]. One resource-leveling calculation method used is modifying the non-critical trajectory to achieve a minimum worker requirement (modified minimum moment). The minimum value is indicated by the value of IF (Improvement Factor).

\[ IF(\text{activity}, S) = \sum w - \sum x - mr \]  

Where,

\( S \) = shifting duration;
\( \sum w \) = number of resource initial duration;
\( \sum x \) = number of resource end duration;
\( m \) = shifting duration implementation;
\( r \) = number of resources.

Before calculating the IF value, categorizing the activities according to the plan and the object of the calculations on activities that are in the non-critical path was performed. Reference to the removal of non-critical track activity can be done by reviewing the previous activity. The activity will be arranged for IF value within the limits of FF [8].

1.3. Resource allocation

Resource allocation is calculated by increasing the project duration. This method limits the number of workers supply (limited resources) and follows per under the needs of the field. By applying the principle of resource leveling before calculating resource allocation, it will be easier to move activities and limit the maximum number of workers. Limiting the workers supply is done to regulate activities (work) in such a way that the workers needed does not exceed the workers supply in the field [9]. Calculation of an increase in project duration (IPD) reviews the activities experiencing conflicts in a certain duration. The conflict in question is a similar activity implemented at the same duration, but the number of workers needed exceeds the worker supply. These activities will be given an increase in dependency relationships according to the following IDP calculation results:

\[ IPD_{ij} = EF_i - LS_j. \]

Where,

\( ij \) = 2 conflict activities;
\( i \) = ES activity is smaller than j activity;
\( j \) = ES activity is bigger than i activity;
\( EF_i \) = early finish i activity;
\( LS_j \) = late start j activity.

2. Methods

The research method used in this research is a non-experimental quantitative method with comparative studies. This study examines and compares the results of efficient workforce scheduling (percentage fluctuations) in two concrete construction implementation systems. The flow of this research shows the steps to achieve the objectives.

2.1. Data collection

Data collection is carried out in a private contractor designing the most efficient construction implementation methods on the Road Bridge construction project. To support the analysis, a case study of planning methods in implementing the precast and conventional concrete system on the Asmat Papua Road Bridge project was conducted. The types of data needed are:

- Schedule of work method in precast and conventional concrete construction, and
2.2. Data processing

Data processing started with modeling the network from data collection in the form of PDM according to their needs. Then, rescheduling was done by calculating resource leveling on activities in which the FF value ≠ 0. Next, the calculation of activity shift (IF) was performed until the scheduling reached its optimum condition, in which the fluctuating scheduling patterns become abnormal or FF = 0. The calculation of improvement factor was stopped if IF = 0 and or negative. Then, data processing with the resource-leveling application was stopped and would be continued at the stage of applying resource allocation. Before scheduling a calculation of resource allocation, rmax value would be determined. Rmax is the maximum cumulative number of workers in the project duration (on a week) used as the worker cap to obtain efficient scheduling conditions. In the first iteration, the rmax is calculated based on the difference in the assumption of decreasing “i” from the largest “i” resulting from the resource-leveling. The rmax in implementing a precast concrete system, a range of 10 people was chosen because 10 people and lower can represent a point of fluctuation in the planning schedule. In implementing a conventional concrete system, a range of 20 people as the representative point of fluctuation was selected. This determination was also based on the calculation of 1/10 of the largest number of “i” in the planning schedule. In each method, a labor restriction is applied according to the specified rmax. The calculation of an increase in project duration (IPD) was performed on activities that experience conflict, in which the number of workers exceeds the rmax in a week. Activities that experience conflicts will be described according to their working relationship. Then, based on the calculation of IPD, activities with minimum IPD will be chosen. The selected activity will change its dependency relationship to finish the previous project to start the next one. The activity is then reviewed for their dependence relationship on the total activity generated in the PDM network. Renewing the network will affect the duration and number of workers needed. The scheduling conditions are already efficient, in which the number of workers in duration has fulfilled rmax and there is no activity allows it to slow down based on its logical relationship. The results of data processing in the form of a new activity scheduling on two implementation methods were based on the specified rmax restrictions.

3. Results and discussion

In the planning schedule for the Asmat Road construction, rescheduling is done by reviewing the number of workforce procurement in two road construction implementation systems: precast concrete and local cast concrete. It is done by applying the principle of resource leveling to reach the assumptions of limiting the number of workers, which is then applied in the calculation of resource allocation to achieve an efficient construction schedule. In the precast concrete implementation system, there are 14 items of work to be done in 14 weeks. Meanwhile, in the conventional concrete implementation system, there are 22 activities planned for 22 weeks. The process of resource leveling and resource allocation is calculated in the duration unit (week).

3.1 Prefabricated concrete implementation system

The precast concrete implementation system was carried out for 14 weeks with the following job descriptions.

Based on the ideal scheduling chart pattern permitted in project construction with R2 approaching 1 and fluctuations to a minimum, scheduling at the limit of 30 people is chosen as the efficient schedule for the precast concrete implementation system. Efficient scheduling for 30 workers lasts for 18 weeks and the fluctuation is 42.39%. Besides, there is also a fluctuation decrease from the planning data by 44.43%. The efficient condition results in scheduling 30 workers, reducing the number of workers to 20 workers compared to the planning data.
Table 1. List of precast concrete system activities and composition of Asmat Road Workforce construction.

| Symbol | Activities                                                                 | Duration (week) | Number of workers (people) |
|--------|-----------------------------------------------------------------------------|-----------------|---------------------------|
| A      | Preliminary work                                                            | 1               | 10                        |
| B      | Components mobilization (Surabaya to Agats)                                 | 4               | 6                         |
| C      | Components mobilization (Agats-Suator-Site)                                 | 9               | 6                         |
| D      | Assembling Precast Pile                                                    | 4               | 10                        |
| E      | Assembling Steel Beam                                                      | 5               | 4                         |
| F      | Steel Pile Cap (212 x 212 x 6) mm, bolt D16 – 250                          | 5               | 4                         |
| G      | Steel WF Beam 150 x 75 x 5 x 7, joint to pile cap bolt D14-40              | 5               | 4                         |
| H      | Steel WF Beam 200 x 150 x 5.5 x 8, joint to steel pipe D6", D14-40        | 5               | 4                         |
| I      | Steel pipe medium galvanize Ø 6” type 1, Steel joint WF 200, sleeve anchor D16-120 | 5               | 4                         |
| J      | Joint steel double 50 x 50 x 5, steel joint WF 200 and WF 150, D14 – 40    | 5               | 4                         |
| K      | Floor Panel Assembling GE F.350. B length = 3 m, 15/60, bolt D16-200       | 6               | 6                         |
| L      | Grouting Floor Panel GE F.350. B                                          | 6               | 6                         |
| M      | Precast curb                                                               | 3               | 4                         |
| N      | Finishing                                                                  | 2               | 4                         |

Figure 4. Resource Allocation scheduling for the precast concrete system
3.2 Conventional concrete implementation system (Local Cast)

The local cast concrete implementation system requires more material, workers, and other types of resources than the precast concrete implementation system. This affects the time, quality, and results in greater project costs. However, without being supported by the efficient distribution of composition from every utilization of available resources, achieving better quality, cost, and time cannot be guaranteed.

Table 2. List of conventional concrete activities and workforce composition for agats-suator project.

| Activity                                      | Duration (week) | Number of workers (people) |
|-----------------------------------------------|-----------------|-----------------------------|
| Preliminary Work                              | 2               | 18                          |
| Supporting Work                               |                 |                             |
| Construction of inspection roads, Length = 1,3m | 2               | 43                          |
| Procurement of Piles                          |                 |                             |
| Procurement of concrete piles K.500, length = 4m (from Distributor to Asmat Port) | 4               | 9                           |
| Shipping concrete piles from Asmat Port (Agats to Project) | 4               | 14                          |
| Road Bridge Concrete Work                     |                 |                             |
| Earthworks for sloof                          | 3               | 6                           |
| Erection concrete piles, length = 4m          | 4               | 51                          |
| Concrete sloof K.225, Size 29,5 x 40 x 300 cm | 3               | 17                          |
| Concrete mold                                 | 3               | 42                          |
| Pile Cap (Reinforced concrete K.225, Size 35 x 35 x 65 cm) | 4               | 5                           |
| Pile Cap mold                                 | 4               | 14                          |
| Scaffolding Pile Cap                          | 4               | 2                           |
| Main Beam (BB. K.225, Uk. 15 x 20 x 300 cm)   | 4               | 4                           |
| Subbeam (BB. K.225, Uk. 15 x 20 x 400 cm)     | 4               | 5                           |
| Main beam and sub beam mold                   | 4               | 25                          |
| Main beam and sub beam scaffolding            | 4               | 8                           |
| Concrete slab. Concrete cover = 10cm (Axles line = 11cm) | 4               | 20                          |
| Slab mold                                     | 4               | 32                          |
| Beam curb (BB. K.225, Uk. 10 x 10 x 15 cm)    | 2               | 4                           |
| Scaffolding beam curb                         | 2               | 10                          |
| Access road bridge wood                       |                 |                             |
| Wood beam, length = 4,0 m dan wide = 2,0 m    | 2               | 2                           |
| Finishing                                     |                 |                             |
| Cleaning finishing                            | 1               | 1                           |

Table 2 above illustrates that the road works consist of five big jobs, each is described according to the volume, duration, and workforce requirements. There is also an activity symbol on each work item. This symbol is used to facilitate the creation of networks.
Based on the restrictions on the number of workers with a decrease of 20 on each largest \( r_{\text{max}} \) or previous iteration, it results in fluctuating scheduling during the construction implementation project. Planning data comparison shows that the allocation of \( r_{\text{max}} = 57 \) people is approaching an ideal condition, in which \( R^2 \) is the closest to 1, and a minimum percentage of fluctuations compared to the results of other iterations.

Scheduling conditions where the \( \max = 57 \) people produced an average fluctuation of 64.2\%, in which the project duration is 32 weeks. Besides, the results of the schedule showed that the percentage of fluctuations decreases by 42\% of the planning data.

![Figure 5. Resource Allocation Scheduling for the Conventional Concrete System](image)

**Figure 5.** Resource Allocation Scheduling for the Conventional Concrete System

### 3.3 Comparison of implementation system for construction of resource allocation

The allocation of worker resources in two construction implementation systems shows that an efficient comparison of scheduling conditions is obtained based on the minimum percentage of fluctuations, and results in scheduling chart patterns that show a strong relationship between the duration and worker cost.

![Figure 6. Scheduling of Efficient Workforce Conditions in the Precast and Conventional Concrete System](image)

**Figure 6.** Scheduling of Efficient Workforce Conditions in the Precast and Conventional Concrete System

Figure 6 shows a consistent scheduling pattern in the precast concrete construction implementation system compared to the conventional concrete implementation system. Although scheduling fluctuations still occur with an average of 43.39\% in precast concrete system and 64.20\% in conventional concrete system, this scheduling is the most efficient condition according to the resource allocation method. The results of efficient scheduling with resource allocation also increases the duration of the project in each implementation system. Efficient conditions on precast concrete are
scheduled for 18 weeks, and conventional concrete for 32 weeks. When compared with planning scheduling data in precast concrete (blue bar in chart), the duration increases by 4 weeks and in conventional concrete (red bar in chart) increases by 10 weeks. The quite significant difference in duration between the two implementation systems is due to activity delays at a certain duration as a result of following the specified worker allocation limits. On the schedule for the precast concrete implementation system, the maximum number of workers is 50. Based on the results of an efficient workforce, the allocation of workers is reduced to 30 people. In this case, savings are made by reducing 20 workers. In the conventional concrete system planning, the maximum number of workers is 137. Based on the results of an efficient workforce allocation, the number of workers is reduced to 57 people. In this case, savings are made by reducing 80 workers. Based on the minimum fluctuation percentage, the precast concrete implementation system shows more efficient scheduling conditions compared to conventional concrete scheduling conditions with a 20.81% difference.

4. Conclusions
The precast concrete construction implementation system achieved efficient conditions at a limit of 30 workers with a minimum fluctuation average of 42.39%, and conventional concrete construction on 57 workers with a fluctuation average of 64.20%. Scheduling the number of workers with resource allocation in the Asmat Papua Road Bridge construction project suggests that scheduling of precast concrete is more efficient with a fluctuation average of 20.81%, lower than that of conventional concrete system scheduling.

References
[1] S Nudja, I Ketut 2016, The requirement planning and resource scheduling in construction project implementation, PADURAKSA, 2, no.2, pp 13-22 (In Bahasa)
[2] Soeharto, Iman 1995, Project management from conceptual to operational, edk, PT.Gelora Aksara Pratama: Jakarta. (In Bahasa)
[3] Novitasari, Vien 2014, The analysis of the acceleration of implementation by increasing optimal working hours on construction projects, UMY Repository, pp 1-45. (In Bahasa)
[4] MS, Easa 1989, Resource leveling in construction by optimization, Journal of construction engineering and management, ASCE, p 115: 2.
[5] Hartono, Widi 2012, Optimalization of human resource allocation with resource leveling, Civil Engineering Media. (In Bahasa)
[6] Kelana, Rama P 2010, Optimizing the use of human resources with the resource leveling method using microsoft project 2007 assistance, Journal of Universitas Sebelas Maret, pp 1-10. (In Bahasa)
[7] Abrar, Husen 2011, Project management, Andi, Yogyakarta. (In Bahasa)
[8] Hendy 2018, Application of resource leveling with the genetic algorithm method in construction projects in Jakarta, Journal of civil engineering partners, 1, no. 2, pp 1-8. (In Bahasa)
[9] Hinze, Jimmie W 2012, Construction planning and scheduling,4th edn, Upper Saddler River, NJ, Pearson Prentice Hall.