

Study on the Influence of Weather Factors on Construction Delays of Retaining Walls in Market Projects

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Article Information	ABSTRACT
Article History Received : March 03, 2025 Revised : March 16, 2025 Published : April 10, 2025	Weather is an external factor that significantly influences the implementation of construction projects, especially in open environments. This research aims to evaluate the impact of weather, particularly rainfall, on delays in retaining wall construction projects in market areas. The study employs statistical analysis of historical weather data, an assessment of work progress realization, and interviews with project implementers. The analysis reveals that rainfall, both drizzle and heavy rain, affects work productivity differently. During the project timeline, rain occurred for 17 days in October (48 hours), 21 days in November (74 hours), and 7 days in December (20 hours). In the first month, progress exceeded the planned schedule with a positive deviation of 4.25%. However, in the second month, adverse weather conditions and other technical factors contributed to a negative deviation of 6.88%. Despite this setback, work progress recovered in the third month, ultimately reaching the targeted 100% completion. Regression analysis confirms that heavy rain significantly hampers construction activities more than drizzle. Significant tasks, such as the construction of retaining walls, come to a complete halt during heavy rain, whereas drizzle still allows work to proceed, albeit with reduced productivity. These findings underscore the necessity of integrating weather risk assessments into project planning to develop more resilient scheduling strategies and minimize potential delays.
Keywords: <i>Weather; Project delays; Construction; Retaining walls; Risk management.</i>	

INTRODUCTION

Implementing construction projects in open environments such as markets is greatly influenced by weather conditions, especially in tropical regions with high rainfall variability. One type of project vulnerable to weather disturbances is the construction of retaining walls, which require soil stability and optimal working conditions. Extreme weather, such as heavy rain and high temperatures, can cause project delays due to reduced labor productivity, changes in soil conditions, and constraints on the use of heavy equipment (Achiari & Maini, 2020; Camilleri et al., 2001; Crawl, 2008; de Wilde & Coley, 2012; Hope et al., 2018; Jalali et al., 2023; Wang et al., 2018).

Given the significant role of weather in construction activities, it is essential to analyze how these external factors impact the sustainability of projects, particularly those in open environments (Schuldt et al., 2021). Heavy rainfall can cause waterlogging at project sites, slow down earthworks, and increase erosion risk. Additionally, extreme temperatures can reduce worker productivity and affect the mechanical properties of construction materials such as concrete

and steel (Kanavaris et al., 2024). These disruptions highlight the necessity of integrating weather considerations into project planning and execution.

One of the critical challenges in retaining wall construction is the increase in water content in the soil due to rain, which can reduce soil-bearing capacity and elevate the risk of landslides (Sheikh et al., 2021).. Water-saturated soil exerts more significant lateral pressure on retaining walls, potentially leading to structural instability if not adequately (Das, 2013; Das & Sobhan, 2012). Thus, ensuring adequate drainage and reinforcement strategies is crucial for the structural integrity of the retaining wall.

Apart from soil stability, temperature extremes also pose risks to construction activities. High temperatures can lead to worker dehydration and reduced efficiency in the field (Battaineh & Odeh, 2002; Odeh & Battaineh, 2002). Furthermore, extreme temperatures affect the concrete curing process, where rapid drying can cause premature cracking and reduce the material's compressive strength. Strategies such as using curing agents or adjusting casting schedules to more stable temperature conditions should be considered to mitigate these effects.

Given these challenges, several mitigation strategies can be implemented to minimize the impact of weather on construction projects. These include more flexible project scheduling, using weather-resistant materials, and installing temporary drainage systems at project sites (Schuldt et al., 2021).. Additionally, real-time weather monitoring technology can provide timely data to anticipate disruptions and adjust construction activities.

Evidence from various case studies underscores the importance of integrating weather considerations into project planning. Projects that fail to account for weather variability often experience significant delays (Hope et al., 2018).. Conversely, those that adopt mitigation measures, such as protective coverings and emergency drainage systems, can better maintain work progress and minimize weather-related setbacks.

Construction delays can have far-reaching consequences in market areas where economic activity is dense, and infrastructure plays a crucial role in community mobility and trade. High rainfall can lead to saturated soil conditions, increasing the risk of landslides and disrupting excavation work and the installation of retaining wall structures (He et al., 2023; Sheikh et al., 2021; Wang et al., 2018). Similarly, extreme temperatures can hinder worker performance and compromise the curing process of concrete, necessitating careful project planning and execution.

While numerous studies have examined the impact of weather on construction projects, research specifically focusing on retaining wall projects in market environments remains limited. Therefore, this study aims to evaluate the impact of weather on the implementation time of retaining wall construction projects in market areas. By addressing these aspects, the research seeks to contribute to better planning and execution of infrastructure projects in weather-sensitive environments.

RESEARCH METHODS

This study uses a quantitative approach with a case study method on a retaining wall construction project in a market area, with the object of research being weather records during the implementation of the project work and the progress of the work on the retaining wall project. Analysis was carried out to evaluate the influence of weather factors on project implementation time by collecting and analyzing historical data and field observations. The research location is a market area that is currently undergoing the construction of a retaining wall. The research object covers all stages of project implementation, especially earthworks, foundations, and retaining wall structures, which are vulnerable to weather changes.

The data used in this research consists of primary data and secondary data. Primary data was obtained through direct observation of project progress during the research period, interviews with the project team—including project managers, field engineers, and workers—and visual documentation and project diaries regarding weather-related obstacles. Meanwhile, secondary data includes historical weather data obtained from field recordings by supervisors from

contractors and project consultants, project planning and realization schedules based on construction management reports, and literature studies on the impact of weather on construction projects. This data is then analyzed using Equation (1) to determine the work weight in preparing an S curve-based schedule, while the actual work progress is calculated using Equation (2) (Aman & Siregar, 2023).

$$\text{Job weight (\%)} = \left(\frac{\text{Job Costs}}{\text{Total Project Cost}} \right) \times 100 \quad (1)$$

$$\text{Progress Realization (\%)} = \left(\frac{\text{Realization of work volume}}{\text{Total Planned Work Volume}} \right) \times \text{Job Weight (\%)} \quad (2)$$

The weight of work obtained can be distributed according to the weekly work plan by dividing the total duration of the implementation period according to the contract. Next, this distribution is mapped in graphical form to produce an S curve on the project implementation schedule, which depicts work progress over time in a structured and measurable manner.

Data analysis was carried out by identifying the independent variable, namely rainfall, and the dependent variable in the form of the duration of project delays at each stage of work. Statistical analysis is carried out by testing the correlation between weather variables and project delays using linear regression or other statistical methods and comparing the planned and actual project times to measure the level of delays. Weather impact evaluation is carried out by determining the weather factors that most influence delays and proposing mitigation strategies to reduce the negative impact of weather on construction projects.

The analysis results were verified by comparing research results with those of previous studies and consulting experts in construction management. In addition, data triangulation was carried out by combining the results of observations, interviews, and statistical analysis to increase the validity of the research. Based on the results of the analysis, this research will formulate recommendations for contractors and stakeholders in managing the impact of weather on retaining wall construction projects, especially in market areas with high levels of activity and dynamic environmental conditions. The following equations in the analysis stage are like an analysis to see the relationship between a weather variable (for example, rainfall) and project delays, which can be analyzed using Equation (3):

$$Y = a + bX + e \quad (3)$$

Where :

Y = duration of project delay (days)

X = weather variables (rainfall)

a = intercept

b = regression coefficient

e = time from the start of the flood to the peak of the flood hydrograph (Hour)

To measure the strength of the relationship between weather variables and project delays, it is calculated using the following Equation (4):

$$R = \frac{n \sum XY - \sum X \sum Y}{\sqrt{(n \sum X^2 - (\sum X)^2)(n \sum Y^2 - (\sum Y)^2)}} \quad (4)$$

Where R has a value between -1 and 1, with a value close to 1 indicating a strong positive correlation and close to -1 indicating a strong negative correlation.

RESULTS AND DISCUSSION

Analysis of Work Weight and Planned Time Schedule

The analysis results using Equation (1) produce a recapitulation of the calculation of the percentage of work weight in the retaining wall construction project at Pasar Pagi, Pangkalpinang City. For example, the weight of the preparatory work is calculated based on the total cost of the preparatory work of IDR 6,800,000, with a project contract value after tax of IDR 483,756,060.20. Using Equation (1), the weight of the preparatory work is calculated as follows:

$$\text{preparatory work weights (\%)} = \left(\frac{\text{IDR 6,800,00}}{\text{IDR 483,756,060.20}} \right) \times 100 = 1.41\%$$

The calculation results show that the preparatory work weights 1.41% of the total project. The main work, namely constructing a retaining embankment at the back along 88.60 meters, has the most significant work weight, 59.22%. In addition, the block pairing work also contributes to the total work weight, which is 7.43%.

Furthermore, external channel work has a work weight of 27.09%, which plays an important role in the project's drainage system. The final stage of work, which includes completion and finishing, has a work weight of 4.86%. Overall, the distribution of the work weight reflects the proportion of each construction element in the project, with the embankment or retaining wall work as the main component that dominates the total work weight.

Figure 1 shows the S-curve of the construction project implementation plan for 70 calendar days. This curve pattern illustrates that initial work progressed slowly due to the preparation stage, then experienced significant acceleration in the middle of the project, and finally slowed down again towards completion. The distribution of work weights shows that the work with the most significant contribution to project progress is in the Rear Supporting Dam and Outer Channel sections, which weigh more than 30%. In contrast, preparatory work has a small weight but is still essential in supporting the smooth implementation of the project.

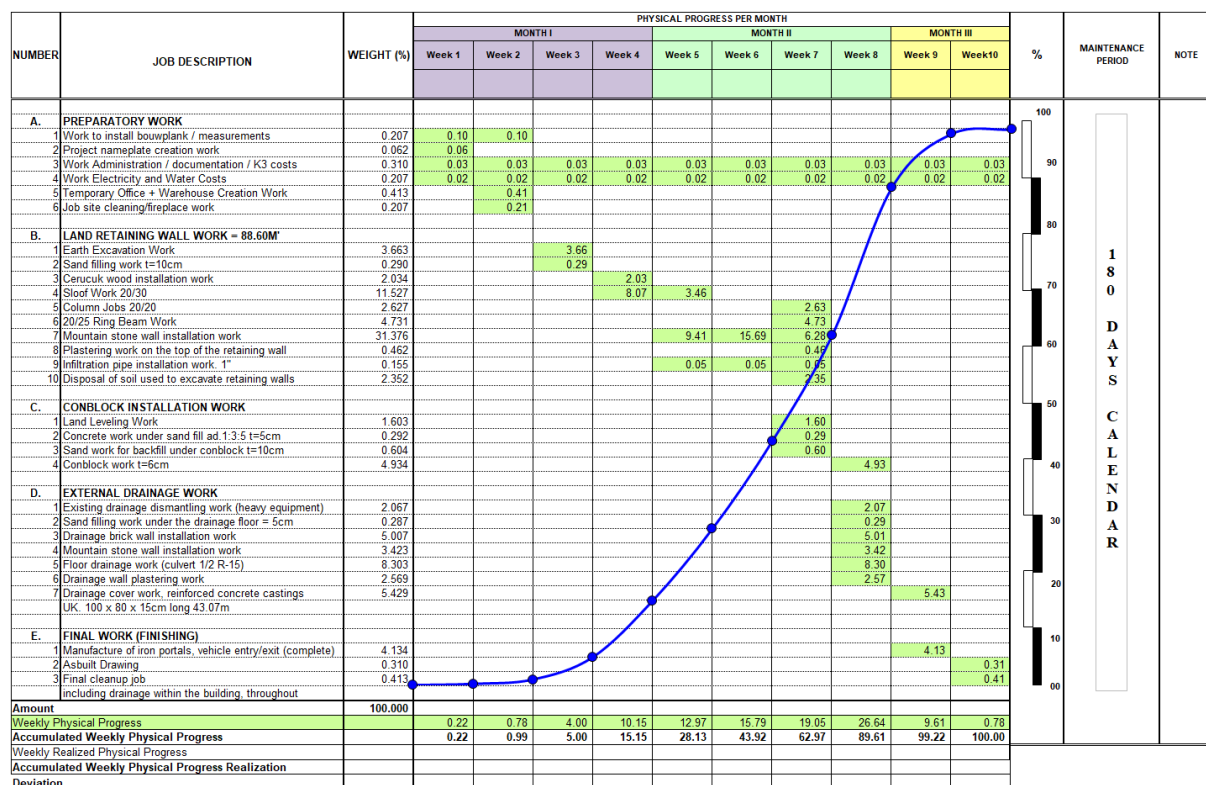


Figure 1. Time Schedule S Curve for Market Land Retaining Wall Construction Project

Based on weekly physical progress, the initial stage of the project has a relatively low completion rate, with weekly progress of less than 1% because it is still in the preparation stage. The peak acceleration occurred in weeks 5 to 10, where weekly progress reached more than 5%, indicating the high intensity of work implementation in that period. After the 10th week, the rate of progress begins to slow until the project reaches completion, with additional progress of around 0.3–0.4% in the final weeks.

Overall, the project follows the ideal S-curve in construction management, indicating that planning and execution were well planned. Most work is concentrated in the middle of the project, reflecting effective work planning after the preparation phase. There are no indications of significant delays because final progress has reached 100% according to the planned time.

Analysis of Weather Recording Realization

Daily reports and special recording officers are prepared in the field to obtain valid weather data records. Data recording is carried out daily from 06.00 WIB to 22.00 WIB with weather condition categories: sunny, cloudy, drizzling, and rainy. Each category is recorded on a recording form by including the start and end times of the weather conditions, thus allowing the calculation of the accumulated duration of the event in hours. Data recording was carried out from October 1, 2023, to December 12, 2023, according to the duration of the project contract. Based on the recording results, it was found that weather conditions had an influence on work productivity in the field. A recapitulation of the results of rain recording during this period is presented in Figures 1 to Figure 3.

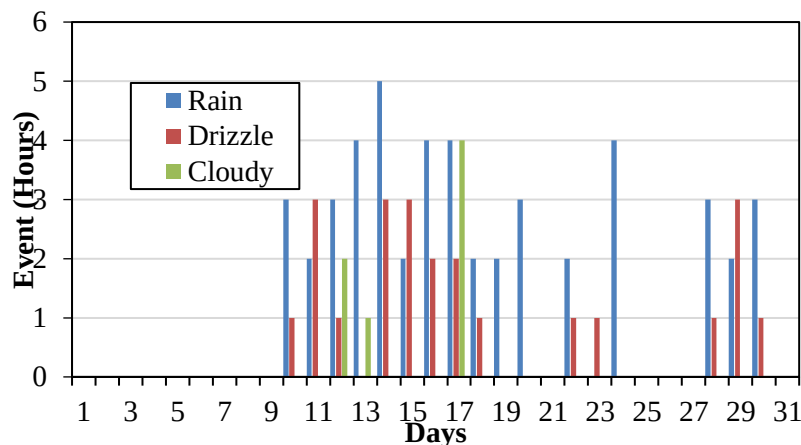


Figure 2. Cumulative Results of Weather Events in the Market Retaining Wall Project in October

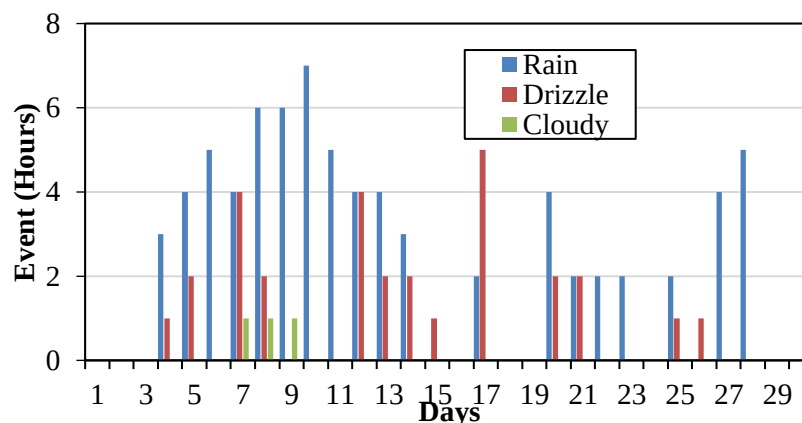


Figure 3. Cumulative Results of Weather Events in the Market Retaining Wall Project in November

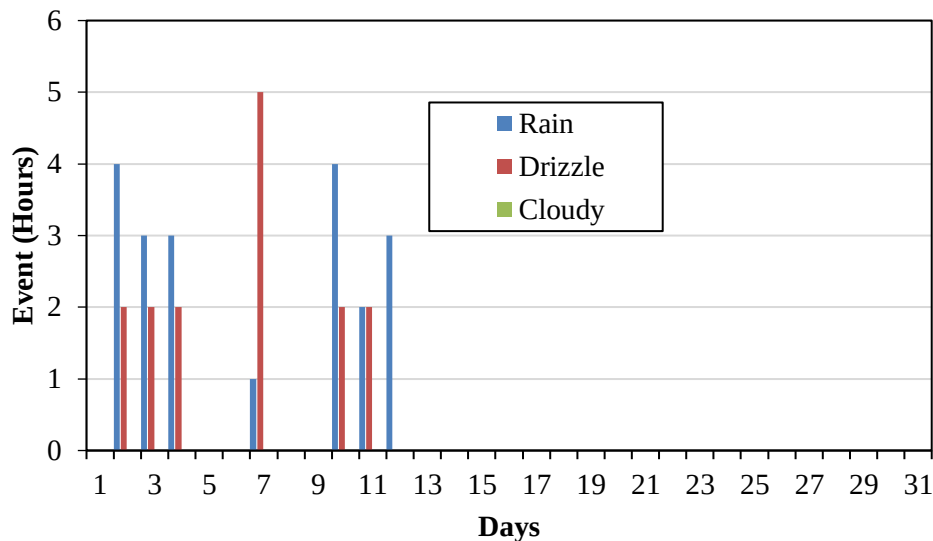


Figure 4. Cumulative Results of Weather Events in the Market Retaining Wall Project in December

Figure 2 presents the results of weather recording during October 2023 at the project location, which took place from October 1 to 31. In that period, rain and drizzle occurred for 17 days. In accumulation, the rain lasted for 48 hours, drizzled for 23 hours, and cloudy conditions were recorded for 7 hours. Meanwhile, Figure 3 displays weather data for November 2023, recorded from November 1 to 30. During this period, rain and drizzle occurred for 21 days, with a total of rain recorded for 74 hours, drizzle for 29 hours, and cloudy conditions only lasting 2 hours. As for December, weather recording will only be carried out from December 1 to 12, 2023, considering that the project contract ends on that date. As shown in Figure 4, rain and drizzle occurred for 7 days, with total rain recorded for 20 hours and drizzle lasting for 15 hours. This data provides an overview of weather conditions at the project site during the last three months before the project was completed.

Analysis of Work Progress Realization in the Field

The results of the analysis of the realization of work progress shown in Figure 5 show the progress of work on the construction of the Pasar Pagi Land Retaining Wall. In the first month of implementation (October 9 to November 5, 2023), the realization of work progress reached 20.32%, higher than the realization plan set at 16.08%. Thus, a positive deviation of 4.25% indicates that work in this period went faster than planned. It indicates efficiency in carrying out work in the early stages of the project.

In the second month of work implementation, from November 6 to December 3, 2023, progress reached 86.86%. This figure is slightly lower than the planned realization target of 93.74%, resulting in a minus deviation of 6.88%. This slowdown in progress can be influenced by various factors, such as unfavorable weather conditions, limited availability of materials, or other technical obstacles that hinder the smooth running of work in the field. Even though there are deviations, efforts to catch up continue to be made so that the project completion target remains on schedule.

Furthermore, in the third month, from December 4 to December 12, 2023, work realization experienced a significant increase and reached 100.00%. This achievement follows the realization plan of 100.00%, which means there is no deviation in project completion in this period. Success in achieving the target shows the effectiveness of the acceleration strategy implemented and the improvement of the performance of the project team. Further details regarding the progress of each work can be seen in Figure 5, while weekly and cumulative progress deviations during the project implementation period are presented in Figure 6.

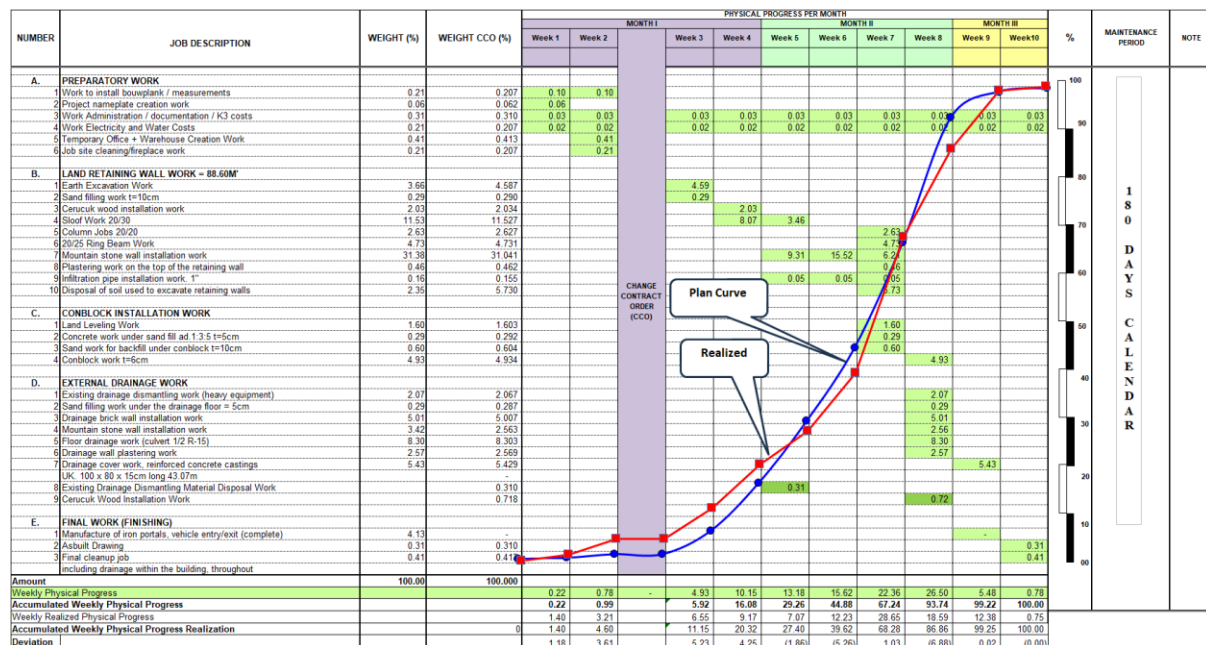


Figure 5. Comparison of the S Curve of Work Progress between Plan and Realization

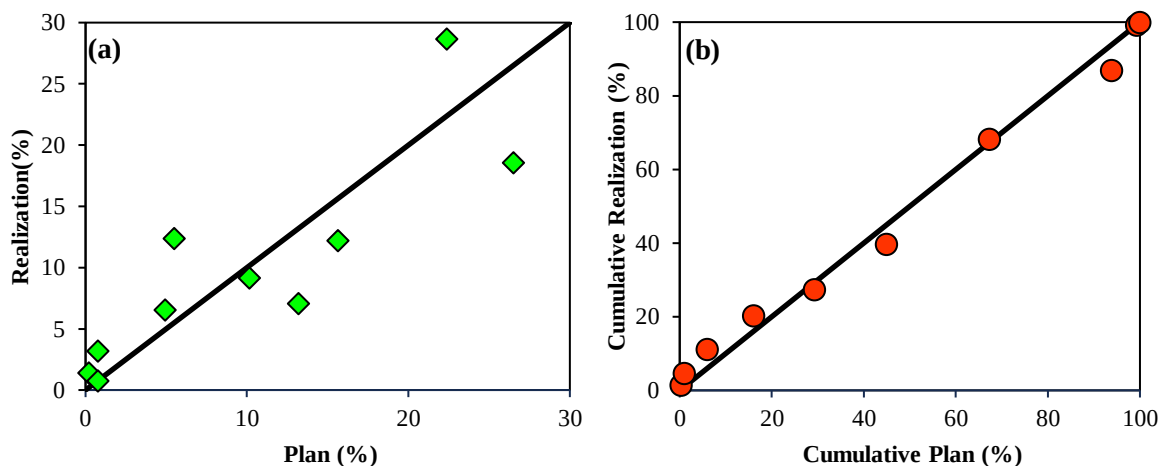


Figure 6. Work Comparison between Plan and Realization: (a) Weekly Progress, (b) Cumulative Progress

Effect of Weather on Work Progress

The results of the analysis of the influence of weather on work progress in the field are shown in Figure 7, which shows a graph of the relationship between cumulative weather duration (in hours) and cumulative work progress (in percent). Data is displayed in two weather conditions categories: rain (denoted by red circles) and drizzle (denoted by green rhombuses).

Two linear regression equations describe the trends for each weather condition. For drizzly conditions, the regression equation has a higher gradient ($1.894x - 29.303$) with $R^2 = 0.9402$, indicating that work is completed more quickly in drizzly conditions than in rainfall. Meanwhile, for rainy conditions, the gradient is lower ($0.7744x - 25.511$) with $R^2 = 0.9228$, indicating that the rain's intensity slows down the progress of the work.

Several data points circled in red indicate deviations in work progress, especially between weeks 6 and 9. This deviation indicates a period with significant obstacles, such as higher-than-normal rain intensity or other factors affecting work efficiency. Given the differences in patterns

between the two weather conditions, the weather significantly affects the work completion rate, with drizzly conditions providing faster progress than heavy rain.

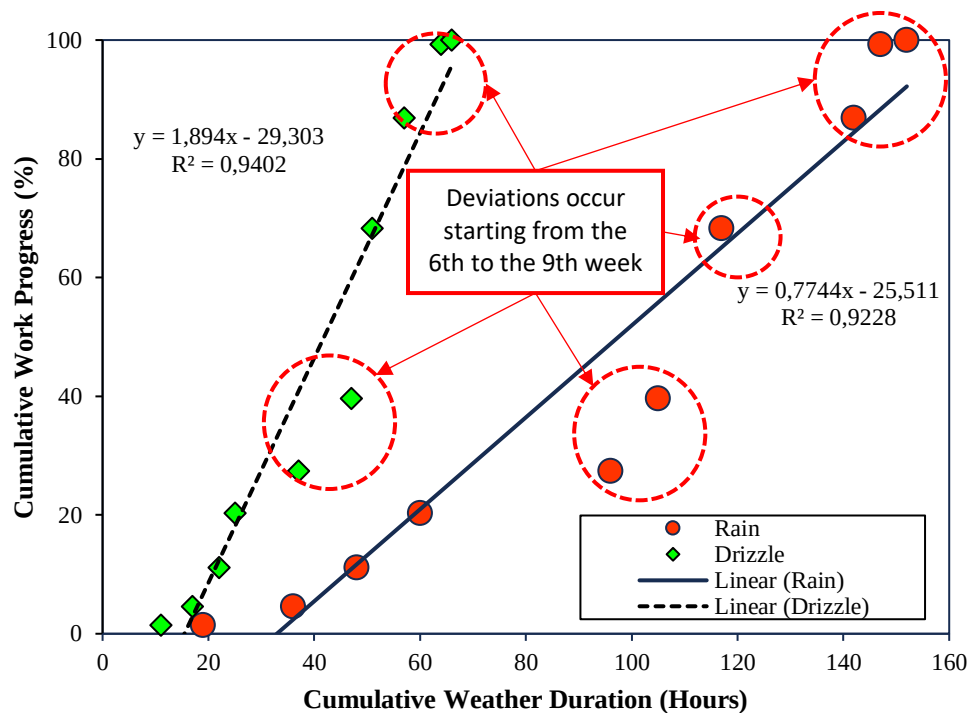


Figure 7. Effect of Weather on Work Progress

Further analysis in weeks 5 to 10 was carried out to understand weather data trends and work progress in the field. Figure 8 shows the relationship between cumulative weather duration (hours) and cumulative work progress (%) for two weather conditions: rain (red circles) and drizzle (green rhombuses). The project experienced a delay deviation of 1.86% in the fifth week, with peak delays in the sixth week (5.26%) and eighth week (6.88%).

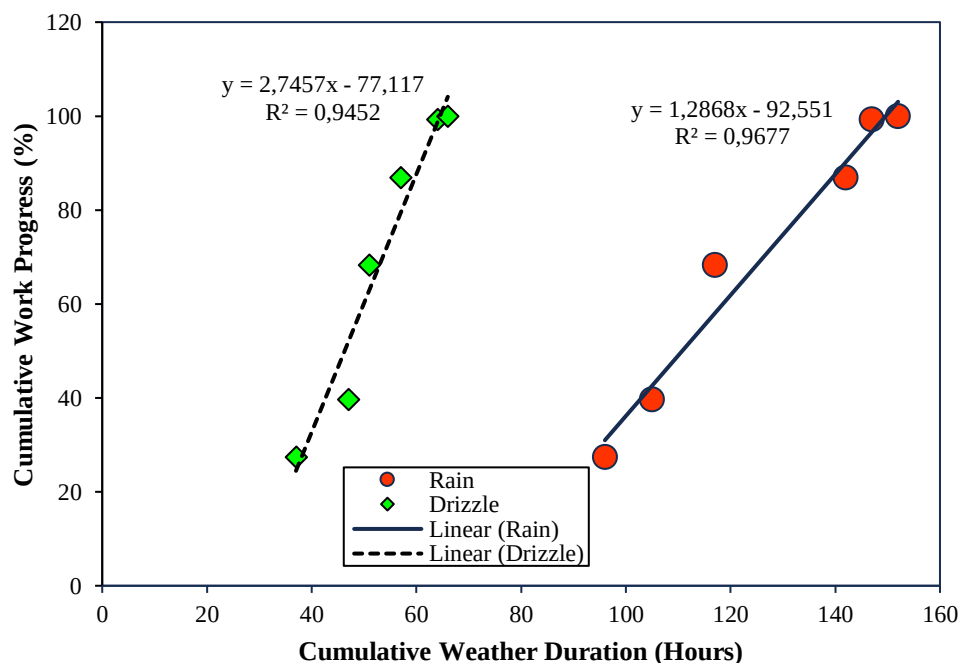


Figure 8. Influence of Weather on Work Delays Week 5 to 10

Weather significantly affects main work, such as embankments or retaining walls. When it rains, work stops completely, while when it rains, it can still be done with lower productivity. Regression analysis shows a strong relationship between weather and work delays. For drizzly conditions, the regression equation is $y = 2.7457x - 77.117$ ($R^2 = 0.9452$), indicating faster progress than rainy conditions with the equation $y = 1.2868x - 92.551$ ($R^2 = 0.9677$). The steeper slope of the regression line in drizzly conditions indicates that each additional weather duration has a more minor impact on delays than rain. Overall, this graph confirms that rain poses a greater obstacle to work progress than drizzle. Therefore, project planning needs to consider weather factors to optimize productivity.

CONCLUSION

The conclusion of this study reveals that rainfall, both drizzle and heavy rain, has different impacts on work productivity. During the project period, rain occurred for 17 days in October (48 hours), 21 days in November (74 hours), and 7 days in December (20 hours). In the first month, the project progress exceeded the planned schedule with a positive deviation of 4.25%. However, in the second month, bad weather conditions and other technical factors caused a negative deviation of 6.88%. The analysis of the relationship between weather conditions and project delays shows a strong influence, as evidenced by the regression value (R), which is more than 0.9. It confirms that heavy rain significantly hampers the productivity of construction work in the field. These findings emphasize the importance of integrating weather risk assessment into project planning to develop more adaptive scheduling strategies and minimize potential delays due to unpredictable weather conditions.

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