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Study on the Prediction of Execution Progress Term Considered the Effect of Climate

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ABSTRACT

The present time there are various problems by the complexity of building, the prediction of progress is difficult in execution progress management and the management of work is difficult, the crash of work often cause and the cooperation in the field is difficult and the like. For this reason when we creat the progress schedule of execution it is important to find out the factor which influence on the progress date of execution and to predict the term on the basis of mathematic method. In many countries they find out the correct the progress term of execution by analysising the factor which influence on the progress term of execution. In this essay the correct progress term of execution is predicted from the statistical analysis about the climate condition which fit in with our actual conditions by mathematic method.

Keywords: term prediction, climate, execution progress management

1 Introduction

When creating the progress schedule for construction execution, the actual progress often does not align with the planned schedule, prompting global studies and experiments to analyze factors affecting execution timelines; as documented in various studies, factors such as work period inaccuracies, resource relativity, and the development of prediction models based on the Critical Path Method (CPM) are considered, with some research suggesting that large-scale projects face uncertainties and require a scientific approach to accurately predict building periods by analyzing these influencing factors [1], [2], [3], [4] highlighting references such as Salem et al. (2005), which discuss the site implementation and assessment of lean construction techniques, further emphasizing the need for innovative strategies to improve construction efficiency and predictability [5].

2 Method

The research methodology involves a comprehensive approach starting with a literature review to identify factors affecting construction timelines. The study collects both quantitative data (e.g., temperature, rainfall) and qualitative assessments of these climate factors. Statistical analysis is employed to understand the probability distribution of these factors, which is assumed to follow a normal distribution. The researchers calculate expected values and variances to quantify the impact of climate on construction progress. The core of the study is the development of a mathematical model that predicts execution progress by integrating these climate factors. The model uses equations to express both quantitative and qualitative influences, adjusting for their individual and combined effects. The model's effectiveness is validated through simulations that predict construction progress under various climate scenarios. The study demonstrates how the model can be used to forecast construction timelines more accurately by considering climate variability. For example, the model is applied to predict the impact of climate on construction activities in specific months, such as July, where temperature and rainfall are significant factors. The results indicate a high probability of construction delays due to climate, with the model providing a systematic way to adjust schedules accordingly. This research highlights the importance of incorporating climate factors into construction planning and offers a quantitative basis for improving execution progress predictions. The study concludes with potential applications in construction management, suggesting that such models can enhance decision-making and resource allocation in the face of climate uncertainty.

3 Result and Discussion

The prediction of the execution progress term by an factor in climate

Assuming that the probability distribution of factors affecting execution progress follows a normal distribution, both qualitative and quantitative elements are considered in this distribution. The prediction of execution terms for these influencing factors is conducted by selecting the target progress term TMTM and identifying the primary factors that predominantly impact progress [6], [7], [8]. Statistical treatments are applied to survey data to calculate probability characteristics, such as expected values and variances. This approach enables the derivation of influence extents for each factor, distinguishing between quantitative and qualitative agents. For quantitative factors, the influence is modeled as ε(x)=δ−axε(x)=δ−ax, where a smaller δδ enhances prediction accuracy [9] [10] [11]. For qualitative factors, the model ε(x)=4δ−5δxε(x)=4δ−5δx is used. By calculating these probability characteristics, the study aims to refine the prediction of execution progress, thereby providing a more scientific and accurate estimation of building periods, as supported by the analysis of climate effects on construction timelines.

$$Ex = \mu = \frac{1}{n}\sum_{i=1}^{n} x_i \tag{1}$$

$$\sigma^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2 \tag{2}$$

Here n : number of survey (experiment) data

x_i : the ith survey data

$\bar{x}$: observer

Derivative that this factor expresses the extent influence on execution progress is derterminded as following type

- the case that effect factor is quantity agent

$$\varepsilon(x) = \delta - ax \ (a > 0) \tag{3}$$

Here $0 < \delta \ll 1$.

δ is different each other in different progress or work,the accuracy of progress prediction model increases.

δ is smaller,the correctness of prediction increase.

- the case that effect factor is qualitative agent

$$\varepsilon(x) = b_s - k_s x = 4\delta - 5\delta x \quad x \in \Omega \tag{4}$$

In this expression, $\varepsilon(x) < \delta \ (0 < \delta \ll 1), \ b_s = 4\delta, \ k_s = 5\delta$

The probability characteristic rates of effect derivative are calculated as following.

- the case that effect factor is quantity agent

Expected value

$$\mu_\varepsilon = \delta - a\mu \tag{5}$$

variance

$$\sigma_\varepsilon^2 = a^2\sigma^2 \tag{6}$$

- the case that effect factor is qualitative agent

Expected value

$$\mu_\varepsilon = 4\delta - 5\delta\mu \tag{7}$$

variance

$$\sigma_\varepsilon^2 = 25\delta^2\sigma^2 \tag{8}$$

The prediction progress function of the execution course is expressed as following expresion

$$T_Y(x) = T_M + \varepsilon(x)T_M = \big(1 + \varepsilon(x)\big)T_M \tag{9}$$

The probability characteristic rates of predition progress function are calculated as following.

- the case that effect factor is quantity agent

Expected value

$$\mu_{T_Y} = T_M + \mu_\varepsilon T_M = T_M + (\delta - a\mu)T_M \tag{10}$$

variance

$$\sigma_{T_Y}^2 = T_M^2\sigma_\varepsilon^2 = T_M^2 a^2\sigma^2 \tag{11}$$

- the case that effect factor is qualitative agent

Expected value

$$\mu_{T_Y} = T_M + \mu_\varepsilon T_M = (1 + 4\delta - 5\delta\mu)T_M \tag{12}$$

variance

$$\sigma_{T_Y}^2 = T_M^2 \sigma_\varepsilon^2 = 25 T_M^2 \delta^2 \sigma^2 \tag{13}$$

The prediction progress term for given fiducial probability is determinded as following.

- The distribution function of prediction progress express as following type.

$$F(T_Y) = \int_{-\infty}^{T_Y} \frac{1}{\sigma_{T_Y}\sqrt{2\pi}} exp\left(-\frac{\left(t - \mu_{T_Y}\right)^2}{2\sigma_{T_Y}^2}\right) dt \tag{14}$$

- When fiducial probability is $p\{\xi < T_Y\}$, the prediction progress term T_Y is determinded by calculating the inverse function of distribution function $F(T_Y)$,

Thus From $F(T_Y) = p\{\xi < T_Y\}$

$$T_Y(p) = F^{-1}(T_Y) \tag{15}$$

The prediction of progress term considered the various effect in climate

Climate factors such as rain, wind, and temperature significantly influence the progress of construction projects. These elements can cause delays, affect resource availability, and alter the efficiency of construction processes. To predict execution progress accurately, it is essential to consider these climate factors [12] [13] [14] [15] [16]. The methodology involves selecting a target progress term, T_M, and identifying the main climate factors impacting progress. Statistical analysis of survey or experimental data is conducted to calculate probability characteristic values, such as expected value and variance, which help quantify the potential impact of these factors. Normalization of data ensures consistency and comparability, allowing for a more precise prediction of execution timelines.

The prediction model incorporates effect derivatives to express the degree of influence each climate factor has on progress. For quantitative factors like temperature, the effect derivative is calculated using specific coefficients, while qualitative factors have their distinct expressions. The prediction function for execution progress is formulated to include these derivatives, enabling a comprehensive analysis of the cumulative impact of various climate conditions. This approach not only enhances scheduling accuracy but also improves resource allocation and risk management, ultimately leading to more efficient project execution. By understanding and accounting for the influence of climate factors, construction managers can better anticipate and mitigate potential delays, ensuring projects are completed on time and within budget.

$$x_i' = \frac{x_i - x_{min}}{x_{max} - x_{min}} \tag{16}$$

Here x_i' : the ith survey(experiment)data normallrized

x_i : the ith survey (experiment) data

x_{max} : maximum value of survey (experiment) data

x_{min} : minimum value of survey (experiment) data

The probability characteristic value of data normallrized are caculated by expression (1),(2).

It determind the effect derivations which express the degree that those factor influence on execution progress.

Determination of effect derivation for every factor conduct by eq.(3),(4).

It calculates the probability characteristic values for effect derivative of every factor.

the probability characteristic values for effect derivative are calculated by eq.(5~8).

The entire effect derivatives that consider the individual effect which every factor influence on execution progress are determinded as following

$$\varepsilon(x_1, x_2, \ldots, x_n) == \sum_{i=1}^{n} \varepsilon(x_i) - \frac{1}{C_2^1} \sum_{\substack{i=1 \\ i \neq j}}^{n} \sum_{j=1}^{n} \varepsilon(x_i \cap x_j) + \frac{1}{C_3^2} \sum_{\substack{i=1 \\ i \neq j \neq k}}^{n} \sum_{j=1}^{n} \sum_{k=1}^{n} \varepsilon(x_i \cap x_j \cap x_k) + \cdots$$
$$+(-1)^{l-1} \frac{1}{C_l^{l-1}} \sum_{\substack{i=1 \\ i \neq j \neq k \neq \cdots \neq l}}^{n} \sum_{j=1}^{n} \sum_{k=1}^{n} \cdots \sum_{\substack{l=1 \\ l<n}}^{n} \varepsilon(x_i \cap x_j \cap x_k \cap \cdots \cap x_l) \quad (17)$$

Here, : the number of effect factor

$\varepsilon(x_i)$: the effect derivative of the ith factor

$x_i, x_j, \ldots, x_l$: $i, j, \ldots, l$ th effect factor

In this case we use following function.

- the case considered only two factor

$$\varepsilon = \sum_{i=1}^{n} \varepsilon(x_i) - \frac{1}{C_2^1} \sum_{\substack{i=1 \\ i \neq j}}^{n} \sum_{j=1}^{n} \varepsilon(x_i \cap x_j) = \varepsilon(x_1) + \varepsilon(x_2) - \frac{1}{2} \varepsilon(x_1 \cap x_2) \quad (18)$$

- the case considered only three factor

$$\varepsilon = \sum_{i=1}^{n} \varepsilon(x_i) - \frac{1}{C_2^1} \sum_{\substack{i=1 \\ i \neq j}}^{n} \sum_{j=1}^{n} \varepsilon(x_i \cap x_j) + \frac{1}{C_3^2} \sum_{\substack{i=1 \\ i \neq j \neq \mathrm{k}}}^{n} \sum_{j=1}^{n} \sum_{\mathrm{k}=1}^{n} \varepsilon(x_i \cap x_j \cap x_\mathrm{k}) \quad (19)$$

We calculate the probability characteristic value of the full of effect derivative.

Each effect element is independent and simultaneous density function is following to;

$$f(x_1, x_2, \ldots, x_n) = f_{X_1}(x_1) f_{X_2}(x_2) \ldots f_{X_n}(x_n)$$

$$= \frac{1}{2\pi\sigma_1\sigma_2 \dots \sigma_n} \exp\left\{-\frac{1}{2}\left[\frac{(x_1-\mu_1)^2}{\sigma_1^2} + \frac{(x_2-\mu_2)^2}{\sigma_2^2} + \cdots + \frac{(x_n-\mu_n)^2}{\sigma_n^2}\right]\right\} \tag{20}$$

Here,

$(x_1, x_2, \dots, x_n)$: simultaneous density function of

effect factor $x_1, x_2, \dots, x_n$

$f_{X_n}(x_n)$: density function of the nth effect element

x_n : the nth effect element

μ_n, σ_n^2 : the Expected value and variance of the nth effect element

If $|\varepsilon| < \delta$ $(0 < \delta \ll 1)$ exist, probability distribution function of the entire effect derivative is same as foll owing.

$$F_\varepsilon(\varepsilon) = P(\mathrm{E} \le \varepsilon)$$

$$= \iint_{\varepsilon(x_1,x_2,\dots,x_n)\le\varepsilon} \frac{1}{2\pi\sigma_1\sigma_2 \dots \sigma_n} \exp\left\{-\frac{1}{2}\left[\frac{(x_1-\mu_1)^2}{\sigma_1^2} + \frac{(x_2-\mu_2)^2}{\sigma_2^2} + \cdots + \frac{(x_n-\mu_n)^2}{\sigma_n^2}\right]\right\} d\,x_1 dx_2 \dots dx_n \tag{21}$$

The probability density function of the entire effect derivative is same as following.

$$f_\varepsilon(\varepsilon) = \begin{cases} \dfrac{dF_\varepsilon(\varepsilon)}{d\varepsilon} & (0 < \varepsilon < \delta) \\ 0 & else \end{cases} \tag{22}$$

Hence the expected value and variance of the entire effect derivative are determinded as following.

$$\mu_\varepsilon = \int_{-\infty}^{+\infty} \varepsilon\, f_\varepsilon(\varepsilon) d\varepsilon = \int_0^\delta \varepsilon\, f_\varepsilon(\varepsilon) d\varepsilon \tag{23}$$

$$\sigma_\varepsilon^2 = \int_{-\infty}^{+\infty} (\varepsilon - \mu_\varepsilon)^2 f_\varepsilon(\varepsilon) d\varepsilon = \int_0^\delta (\varepsilon - \mu_\varepsilon)^2 f_\varepsilon(\varepsilon) d\varepsilon \tag{24}$$

The prediction progress function of execution progress expresses by eq. (9).

The probability characteristic values of prediction progress function are calculated by using eq. (10~13)

We determind the prediction progress term for the given fiducia

fiducial probability by calculating the inverse function of the distribution function.

Prediction building time considered climate condition in our country

To address this, we incorporate climate factors into the prediction of construction timelines. For instance, when planning wall concrete work scheduled for July, it is crucial to consider the effects of climate conditions, such as temperature and rainfall, on the building process. By analyzing historical climate data and applying statistical methods, we can estimate the expected value and variance of these effects, allowing for a more accurate prediction of the construction timeline. In this specific case, the target completion time, $T_M = 31$, is set at 31 days. We use mathematical models to assess the impact of climate factors, such as rain and temperature, on this timeline. For example, if the temperature exceeds 33°C or rainfall surpasses 100 mm, construction activities may be delayed. By calculating the expected values and variances for these climate effects, we can adjust the predicted progress term accordingly. This approach not only provides a more realistic schedule but also enhances risk management by anticipating potential delays due to adverse weather conditions. As a result, construction managers can better prepare and allocate resources, ensuring that projects are completed efficiently and within the anticipated timeframe.

From given condition target time $T_M = 31$ and factor is climate and rain effect.

x_1 is the effect of climate, using the equation 16 regulate survey data, and then calculate the probavility chara cter using the equation 1,2.

So mathematic expected value and dispersion value is followed regular dispersion $\mu_1' = 0.58,\ \sigma'^2_1 = 0.16^2$.

x_2 is the effect of rain and according to the same method calculate the regulated survey data.

Exept the no rain day and day that rained bellow 10mm.

So mathematic expected value and dispersion value is followed regular dispersion

$$X_1' \sim N(0.58, 0.16^2) \quad x_1'_{max} = 1, \qquad x_1'_{min} = 0$$

$$X_2' \sim N(0.14, 0.156^2) \quad x_2'_{max} = 1, \qquad x_2'_{min} = 0$$

$$U' = [0,1] \times [0,1]$$

Temperature and no factor are fixed quantity so decide the effect derivative function by equation 3.

Let decide the coefficient δ_1, a_1 in the effect derivative function of temperature.

In the case high temperature is bellow 20°C, it doesn't effect to work and if the temperature is above 20°C it start to effect to work, if it is above 33°C we can not work.

Thus, temperature is 33°C, $T_Y = 31(1 + \varepsilon(x_1))$ by this equation the predict progress increase more one day, if temperature is bellow 20°C $\varepsilon(x_1) = 0$ and else $\varepsilon(x_1) \approx 0.032$.

According to this, calculate the coefficient δ_1, a_1, $a_1' = -0.0429$,

$\delta_1' = -0.0035$ so effect derivative function expression of temperaure is bellow.

$$\varepsilon(x_1') = \delta_1' - a_1' x_1' = 0.0429 x_1' - 0.0035 \qquad x_1' \in [0.08, 0.83]$$

If temperature is $x_1 < 20$°C, derivative is $\varepsilon = 0$, if $x_1 > 33$°C derivative is $\varepsilon = 0.032$.

Expective value and valience of Influence function of temperature is calculated by equation 5,6.

$$\mu_{\varepsilon(x_1')} = \delta_1' - a_1' \mu_1' = 0.0429 \times 0.58 - 0.0035 \approx 0.02$$

$$\sigma^2_{\varepsilon(x_1')} = a'^2_1 \sigma'^2_1 = 0.0429^2 \times 0.16^2 \approx 0.007^2$$

Let decide the coefficient δ_2, a_2 in the effect derivative function of rain $\varepsilon(x_2) = \delta_2 - a_2 x_2$.

Rain of above 10mm start to effect, if it is above 100mm we cannot work.

Thus if rainfall is 100mm, by this equation $T_Y = 31(1 + \varepsilon(x_1))$ the predict progress increase more one day s o $\varepsilon(x_3) = 1/31 \approx 0.032$.

Thus calculate by regulated data, result is $a_2{}' = -0.067,\ \delta_2{}' = -0.0032$.

The expression equation of rain is bellow.

$$\varepsilon(x_2{}') = \delta_2{}' - a_2{}'x_2{}' = 0.067x_2{}' - 0.0032 \quad x_2{}' \in [0, 0.46]$$

Expective value and valience of Influence function of rain is calculated by equation 5,6. Thus

$$\mu_{\varepsilon(x_2{}')} = \delta_2{}' - a_2{}'\mu_2{}' = 0.067 \times 0.14 - 0.0032 \approx 0.006$$

$$\sigma^2_{\varepsilon(x_2{}')} = a'^2_2\sigma'^2_2 = 0.067^2 \times 0.156^2 \approx 0.0105^2$$

Decide all of effect function using equation 18.

$$\varepsilon = \sum_{i=1}^{n} \varepsilon(x_i) - \frac{1}{C_2^1} \sum_{\substack{i=1 \\ i \neq j}}^{n} \sum_{j=1}^{n} \varepsilon(x_i \cap x_j) = \varepsilon(x_1) + \varepsilon(x_2) - \frac{1}{2}\varepsilon(x_1 \cap x_2)$$
$$= \varepsilon(x_1) + \varepsilon(x_2) - \frac{1}{2}\varepsilon(x_1)\varepsilon(x_2)$$
$$= a_1(1 + 0.5\delta_2)x_1 + a_2(1 + 0.5\delta_1)x_2 - 0.5a_1a_2x_1x_2 - (\delta_1 + \delta_2 + 0.5\delta_1\delta_2)$$

So

$$\varepsilon(x_1{}', x_2{}') = 0.0445x_1{}' + 0.069x_2{}' - 0.0014x_1{}'x_2{}' - 0.0067$$

$$\varepsilon(x_1{}', x_2{}') = \begin{cases} 0 \\ 0.0445x_1{}' + 0.069x_2{}' - 0.0014x_1{}'x_2{}' - 0.0067 \\ 0.0429x_1{}' - .0035 + 0.032 \\ 0.067x_2{}' - 0.0032 + 0.032 \\ 0.064 \end{cases}$$

$$\begin{array}{c} (x_1{}', x_2{}' | x_1{}' \leq 0.08, x_2{}' \leq 0) \\ (x_1{}', x_2{}' | x_1{}' \in (0,0.83], x_2{}' \in (0,0.46]) \\ (x_1{}', x_2{}' | x_1{}' \in (0,0.83], x_2{}' \in (0.46,1)) \\ (x_1{}', x_2{}' | x_1{}' \in (0.83,1), x_2{}' \in (0,0.46]) \\ (x_1{}', x_2{}' | x_1{}' \geq 0.83, x_2{}' \geq 0.46) \end{array}$$

Whole effect function diagram is figure 1.

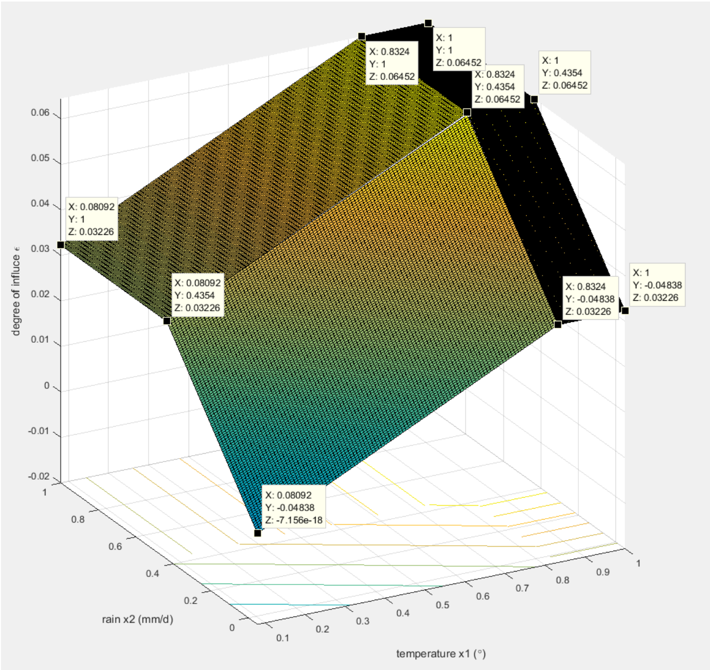

Figure 1 Graphical Representation of Climate Impact on Construction Progress

The same time probability density function is presented like bellow and the diagram is bellow (Figure 2).

$$f(x_1', x_2') = f_{X_1'}(x_1') f_{X_2'}(x_2') = \frac{1}{2\pi\sigma'_1\sigma'_2} \exp\left\{-\frac{1}{2}\left[\frac{(x_1' - \mu_1')^2}{\sigma'^2_1} + \frac{(x_2' - \mu_2')^2}{\sigma'^2_2}\right]\right\}$$

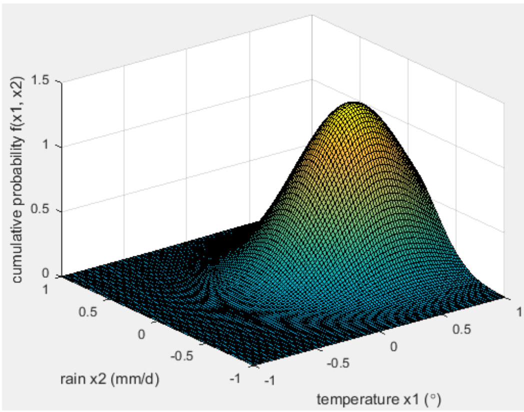

Figure 2 Probability Density Function of Combined Climate Effects on Construction Progress

Probability fuanction of whole effect function is expressed by equation 21.

$$F_\varepsilon(\varepsilon) = P(\mathrm{E} \le \varepsilon)$$
$$= \iint_{\varepsilon(x_1, x_2) \le \varepsilon} \frac{1}{2\pi\sigma_1\sigma_2} \exp\{-\frac{1}{2}\left[\frac{(x_1 - \mu_1)^2}{\sigma_1^2} + \frac{(x_2 - \mu_2)^2}{\sigma_2^2}\right]\} d\, x_1 dx_2$$

Also probability density function of whole effect function is expressed by equation 22.

$$f_\varepsilon(\varepsilon) = \begin{cases} \dfrac{dF_\varepsilon(\varepsilon)}{d\varepsilon} & (0 < \varepsilon < \delta) \\ 0 & else \end{cases}$$

Expective value of whole effect function is by equation 23

$$\mu_\varepsilon = \int_{-\infty}^{+\infty} \varepsilon f_\varepsilon(\varepsilon) d\varepsilon = \int_{0}^{\delta} \varepsilon f_\varepsilon(\varepsilon) d\varepsilon =$$

$$= \iint_{\varepsilon(x_1,x_2)\le\varepsilon} \varepsilon(x_1, x_2)\sqrt{1+{\varepsilon'_x}^2+{\varepsilon'_y}^2} f_\varepsilon(\varepsilon) d\, x_1 dx_2$$

so

$$= \frac{1}{2\pi\sigma'_1\sigma'_2} \iint_{\varepsilon(x_1,x_2)\le\varepsilon} \varepsilon(x_1', x_2')\sqrt{1+{\varepsilon'_x}^2+{\varepsilon'_y}^2} \exp\left\{-\frac{1}{2}\left[\frac{(x_1'-\mu_1')^2}{{\sigma'}_1^2}+\frac{(x_2'-\mu_2')^2}{{\sigma'}_2^2}\right]\right\} d\, x_1 dx_2$$

$$(\varepsilon'_x = 0.0429 - 0.0015 x_2' \ \ , \ \ \varepsilon'_y = 0.07 - 0.0015 x_1' \ )$$

In before equation replace $\mu_1' = 0.58$, $\mu_2' = 0.14$, ${\sigma'}_1^2 = 0.16^2$, ${\sigma'}_2^2 = 0.156^2$, $\varepsilon(x_1', x_2')$ and calculate result is

$$\mu_\varepsilon = 0.0307$$

Variance of whole effect function is by equation 24

$$\sigma_\varepsilon^2 = \int_{-\infty}^{+\infty} (\varepsilon-\mu_\varepsilon)^2 f_\varepsilon(\varepsilon) d\varepsilon = \int_{0}^{\delta} (\varepsilon-\mu_\varepsilon)^2 f_\varepsilon(\varepsilon) d\varepsilon$$

$$= \iint_{\varepsilon(x_1,x_2)\le\varepsilon} [\varepsilon(x_1, x_2)-\mu_\varepsilon]^2\sqrt{1+{\varepsilon'_x}^2+{\varepsilon'_y}^2} f_\varepsilon(\varepsilon) d\, x_1 dx_2$$

$$= \frac{1}{2\pi\sigma'_1\sigma'_2} \iint_{\varepsilon(x_1,x_2)\le\varepsilon} [\varepsilon(x_1', x_2')-\mu_\varepsilon]^2\sqrt{1+{\varepsilon'_x}^2+{\varepsilon'_y}^2} \exp\left\{-\frac{1}{2}\left[\frac{(x_1'-\mu_1')^2}{{\sigma'}_1^2}+\frac{(x_2'-\mu_2')^2}{{\sigma'}_2^2}\right]\right\} d\, x_1 dx_2$$

In before equation replace $\mu_\varepsilon = 0.0336$, $\mu_1' = 0.58$, $\mu_2' = 0.14$, ${\sigma'}_1^2 = 0.16^2$, ${\sigma'}_2^2 = 0.156^2$, $\varepsilon(x_1', x_2')$ a nd calculate result is

$$\sigma_\varepsilon^2 = 0.0335$$

Expective progress function is bellow by equation 9.

$$T_Y = T_M\big(1+\varepsilon(x_1, x_2)\big)$$

Expective value and vaiance of expective progress function is calculated by equation 4-10,4-11.

$$\mu_{T_Y} = T_M(1+\mu_\varepsilon) = 31(1+0.0307) = 31.95$$

$$\sigma_{T_Y}^2 = T_M^2\sigma_\varepsilon^2 = 31^2 \times 0.0335^2 = 1.04^2$$

Time limit that expective value T_Y 99% is calculated by equation 15.

In calculation result $T_Y = 4.65$.

So in july, probability that progress is extended by effect of climate is 99% (Figure 3).

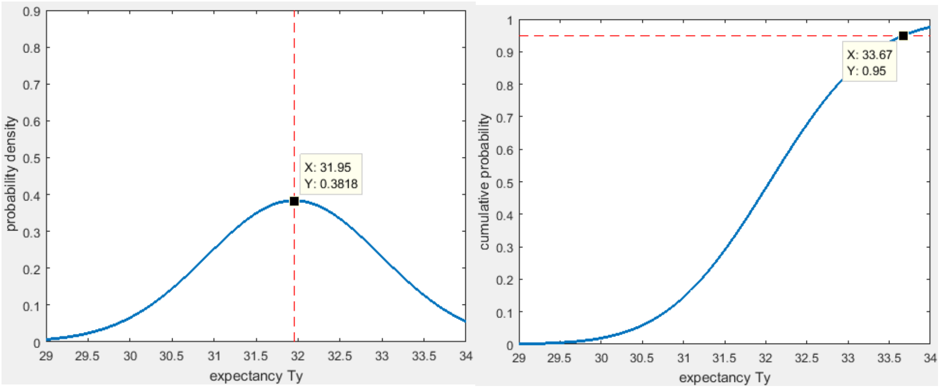

Figure 3 Probability Density Function of Climate-Induced Progress Delays

According to the same method, we consider in the period from march to may the effect of wind and rain, in ju ne the effect of wind and temperature, from july to August the effect of temperature and rain, from Septembe r to November the effect of wind and rain, probability of extension in each month is bellow (Table 1).

Table 1 prediction period considered effect of climate

month	Effect of climate	Extention day
		99%
3	Wind,rain	1.50
4	Wind,rain	2.88
5	Wind,rain	3.73
6	Wind,temperature	3.86
7	Temperature, rain	4.65
8	Temperature, rain	5.89
9	Wind,rain	2.93
10	Wind,rain	1.58
11	Wind,rain	1.42

4 Conclusion

This study presents a comprehensive approach to predicting construction project timelines by incorporating climate factors, particularly temperature and rainfall. The research develops a mathematical model that quantifies the effects of these climate factors on construction progress, using statistical analysis and probability distributions to predict the likelihood of climate-induced delays. The methodology involves selecting a target progress term and identifying key climate factors impacting construction. Statistical analysis of survey data is conducted to calculate probability characteristics, such as expected values and variances, which help quantify the potential impact of these factors. The model uses equations to express both quantitative and qualitative influences, adjusting for their individual and combined effects. A case study focusing on wall concrete work scheduled for July demonstrates the model's application. By analyzing historical climate data, the study estimates the expected value and variance of climate effects on the construction timeline. The results indicate a 99% probability of project extension in July due to climate effects, with an estimated 4.65-day delay. The research extends this analysis to other months, considering various climate factor combinations such as wind and rain in spring and fall, and temperature and rain in summer. This approach provides a month-by-month breakdown of potential extension days throughout the year, offering valuable insight for seasonal planning in construction projects. This model contributes significantly to construction management by offering a quantitative method to incorporate climate risk into project scheduling. It enables project managers to better anticipate delays, allocate resources more efficiently, and improve overall project planning and execution. The study concludes by suggesting potential applications and future research directions to enhance the model's effectiveness across diverse geographical regions and climate conditions.

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6 Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. All authors have approved the final version of the manuscript and agree with its submission to the journal. These sections should be tailored to reflect any specific contributions, funding sources, or potential conflicts relevant to the actual research and authors involved. If there are specific individuals or organizations that contributed to the research, they should be acknowledged appropriately. Similarly, any conflicts of interest should be disclosed transparently.

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