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Adjusting the Project Schedule by Pre-Control Chart

Ali Rahimifard[1,*], Mohammadreza Sharifi Ghazvini[2]

[1] Department of Industrial Engineering, Mal. C, Islamic Azad University, Malayer, Iran; a.rahimifard@iau.ac.ir.
[2] Department of Industrial Engineering, Deh. C, Islamic Azad University, Isfahan, Iran; Mo.sharifi@iau.ac.ir.

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Abstract

In contemporary project management practices, one of the most pressing challenges is the establishment of a reliable and adaptable project schedule that accounts for potential variations and allows sufficient time for revisions prior to implementation. Traditional scheduling techniques often fall short of providing structured mechanisms for dealing with schedule uncertainty, feedback loops, and control adjustments. This paper introduces a novel and practical methodology that integrates Monte Carlo simulation with Pre-control chart techniques to enhance planning precision and risk-informed decision-making. The approach is further supported by the capabilities of Primavera risk analysis software, enabling the identification of critical risk zones, evaluation of control intervals, and visualization of project performance against predetermined control boundaries. The innovation of this research lies in the application of univariate pre-control charts—initially designed for industrial quality control—into the domain of project scheduling and monitoring, offering project managers a scientifically grounded and visually interpretable framework for schedule adjustment and control. The proposed methodology not only facilitates early detection of deviations but also provides a structured algorithm for schedule revision, ensuring that corrective actions can be implemented proactively. A case-based illustration is presented to demonstrate the practical implications and advantages of this integrated method in a real-world project context. The results indicate that the use of pre-control charts within a probabilistic scheduling environment leads to improved schedule reliability, better resource alignment, and enhanced preparedness for execution. This study lays the foundation for future research on extending pre-control logic to multi-objective project management domains, such as cost and quality control, thereby contributing to the development of integrated and adaptive control strategies for complex projects.

Keywords: Project management, Pre-control, Simulation, Scheduling, Monte Carlo method, Practical.

1 | Introduction

Effective schedule management remains a cornerstone of successful project execution. "Plan Schedule Management" is a systematic process aimed at establishing the necessary policies, procedures, and documentation required to plan, develop, manage, execute, and control the project schedule throughout its lifecycle. The primary benefit of this process lies in providing a structured framework that guides project

Corresponding Author: a.rahimifard@iau.ac.ir

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stakeholders on how the schedule will be monitored and adjusted in response to performance deviations or emerging constraints. A well-defined schedule management plan not only ensures consistency in schedule oversight but also facilitates alignment among project team members regarding critical milestones, deadlines, and response mechanisms.

The schedule management plan itself serves as an integral component of the overall project management plan. Depending on the complexity and nature of the project, it may range from informal and broadly defined to highly detailed and formalized.

Importantly, the plan incorporates appropriate control thresholds and mechanisms for dealing with schedule uncertainties. These include predefined protocols for assessing schedule contingencies, reporting deviations, and initiating corrective actions. As the project progresses, the schedule management plan can and should be updated to reflect any changes in strategy, tools, or stakeholder expectations [1].

One of the critical challenges in project scheduling is the ability to detect early deviations and implement timely corrective actions before delays propagate across the project timeline. Traditional monitoring techniques, such as Earned Value Management (EVM) and Statistical Process Control (SPC), often require a substantial amount of historical data before control boundaries can be established. This may limit their responsiveness during the early phases of a project. To address such limitations, methodologies rooted in manufacturing process control offer promising alternatives.

In 1953, a team from Rath & Strong, Inc. introduced the concept of pre-control, which later gained attention as a simplified and intuitive alternative to Shewhart control charts. Initially developed for monitoring test units in manufacturing environments, pre-control—also known as "stoplight control"—employs a visual and categorical framework using three color-coded zones: Green, yellow, and red. This classification enables rapid decision-making based on the quality status of a small sample, empowering frontline operators to halt defective production at early stages.

Pre-control is not only easy to implement and interpret but also possesses solid statistical characteristics. Unlike SPC methods that typically demand a minimum of 25 subgroups to establish reliable control limits, pre-control provides meaningful feedback almost immediately. This makes it particularly valuable in dynamic environments where real-time responsiveness is essential.

In the pre-control framework, technical tolerances are partitioned into three bands, where the central region of the specification range is designated as the green zone, indicating acceptable performance. Key terms used in this context include Upper Specification Limit (USL), Lower Specification Limit (LSL), Upper Pre-Control Limit (UPCL), Lower Pre-Control Limit (LPCL), and Target (T), all of which are instrumental in defining acceptable process boundaries and triggering intervention when needed.

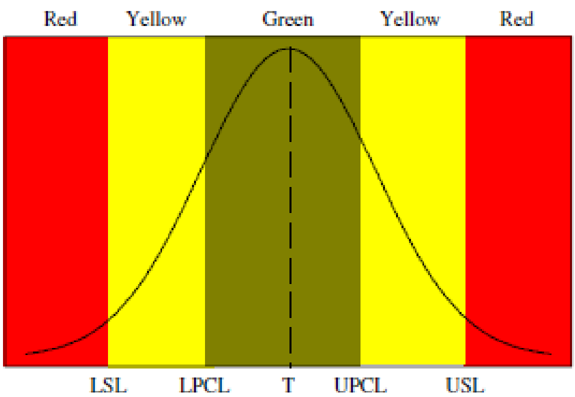

Fig. 1. Univariate pre-control chart for a normal distribution.

Satterthwaite was among the pioneers in developing an early form of pre-control charting by introducing a straightforward yet powerful univariate pre-control chart, as illustrated in *Fig. 1*. This tool represented a fundamental departure from the more complex Shewhart control charts and offered a practical framework for frontline operators to manage process quality without the necessity for advanced statistical training. Subsequent elaborations by Ledolter and Swersey [2] helped formalize its operational rules and monitoring logic, thereby solidifying its theoretical and practical foundation. The principles underlying this chart can be articulated through five core assumptions and operational rules:

Assumption of normality: The process output is presumed to follow a normal distribution, a standard supposition in statistical quality control that facilitates probabilistic interpretation and zone classification.

Target centering: The process target is defined as the midpoint between the upper and LSLs (USL and LSL, respectively). This central value provides a benchmark for performance evaluation.

Zonal demarcation: The tolerance range is divided into three zones—green, yellow, and red—based on two internal control lines (Upper and LPCLs: UPCL and LPCL). The green zone, constituting the central half of the total tolerance, denotes optimal performance. The yellow zones, situated between the green and the specification boundaries, indicate caution and potential drift. The red zone, beyond the LSL or USL, signals nonconformance and mandates immediate corrective action.

Setup rule: Prior to commencing full-scale production, a setup validation procedure is executed. The operator samples five consecutive units. If all five reside within the green zone, the setup is considered statistically capable, and production may proceed. If this condition is not satisfied, machine adjustments or calibration are necessary.

Operational monitoring during production: If two successive units fall within the green zone, the process is deemed stable.

A combination of one green and one yellow sample allows production to continue under caution. Two yellow zone readings, whether in the same or opposite sub-zones, suggest a shift in central tendency or increase in variation, requiring process suspension and investigation. Any single red zone reading constitutes a breach of quality assurance thresholds and demands an immediate stop for root cause analysis. Compared to traditional Shewhart charts, pre-control charts offer significant advantages in terms of simplicity, responsiveness, and operator accessibility.

They eliminate the need for continuous plotting, subgroup averaging, or standard deviation calculation. The visual logic of color-coded zones makes them especially suitable for environments where real-time quality decisions must be made rapidly by non-specialist personnel.

Evans and Lindsay [3] provide a comprehensive theoretical foundation for these charts, including interpretations under varying conditions of process capability. In practical domains, pre-control charts have found diverse applications.

For instance, they have been employed to ensure process stability in small batch production lines [4], assess and manage safety-related risks in mining operations [5], and facilitate risk mitigation in project environments through early warning indicators and proactive intervention mechanisms [6]. Furthermore, in multi-project engineering contexts such as large-scale construction enterprises, pre-control strategies have been adapted to coordinate quality performance across parallel workflows.

A noteworthy application is illustrated in a case study from a U.S.-based medical wire manufacturing firm, where the integration of pre-control charts into a six Sigma quality enhancement framework led to a measurable improvement in process predictability. Specifically, the implementation contributed to a marked increase in the coefficient of determination (R^2), indicating a higher proportion of variance explained by the process model [7].

Building upon these foundations, the present study proposes an integrated methodology that merges project scheduling techniques with pre-control charting principles. This hybrid approach offers a dual advantage: it supports the formulation of robust implementation plans while simultaneously embedding dynamic monitoring and feedback mechanisms into the project lifecycle.

Such an approach enhances not only the accuracy and adaptability of scheduling but also the overall governance of project execution. It also facilitates the identification and resolution of residual tasks, verification of procedural correctness, and the accommodation of necessary plan modifications in response to emerging deviations or risks.

2 | Literature Review

The integration of SPC techniques into project management has advanced significantly with the aid of Artificial Intelligence (AI) and data-driven methodologies. Recent studies have developed AI-based prediction control charts that enhance the monitoring and improvement of project processes, enabling project teams to identify deviations and implement corrective actions more effectively [8]. These approaches combine traditional statistical indicators with real-time learning capabilities to adapt to dynamic project environments [9].

In parallel, the combination of the Program Evaluation and Review Technique (PERT) and the Critical Path Method (CPM) remains one of the most reliable approaches for managing time, cost, and uncertainty in complex projects. Recent research emphasizes their combined use for generating realistic project schedules and managing changes dynamically during execution.

For instance, Calp and Akcayol [10] demonstrated the efficiency of using genetic algorithms in optimizing CPM/PERT scheduling networks under uncertainty, which enhances both flexibility and accuracy in scheduling decisions.

Moreover, the use of multivariate control charts in project performance evaluation, particularly through EVM and Earned Duration Management (EDM), has proven effective in tracking time and cost performance simultaneously. These charts provide early warning signals and allow for the timely resolution of issues, improving project success rates [11]. Advanced quality control models have integrated Multivariate Statistical Process Control (MSPC) with EVM indicators to simultaneously monitor deviations in cost and schedule performance [12].

Some researchers have also investigated the use of SPC tools like pre-control charts to monitor project activities, especially in production and engineering projects. These tools serve as a simpler alternative to traditional control charts when assumptions about data distribution cannot be guaranteed [13].

Pre-control charts are particularly beneficial in the early detection of process variation when historical process behavior is unknown or unstable, which is often the case in complex and non-repetitive project environments. According to Seyisoglu et al. [14], using such charts to monitor activity durations in dynamic projects can effectively reduce the detection time of abnormal variations and support proactive management.

More recently, efforts have been made to integrate machine learning models into project scheduling systems, improving responsiveness to unexpected delays or disruptions. These dynamic scheduling models have outperformed static CPM-based plans in metrics such as average delay, resource allocation, and cost efficiency [15]. The fusion of pre-control charts with predictive models offers potential for real-time feedback systems, particularly when managing high-variability activities such as those found in construction or IT projects [16].

Together, these advancements suggest a promising future where traditional project scheduling methodologies are enhanced through statistical, AI-driven, and adaptive tools. This paper aims to contribute by proposing a novel framework that incorporates pre-control charts within the CPM/PERT scheduling environment, aiming to offer real-time visual feedback to project managers, especially in settings where process stability cannot be assumed in advance.

3 | Methodology

The proposed methodology is structured around three core elements: simulation, pre-control charts, and schedule monitoring mechanisms. The rationale is to proactively identify deviations and enable timely revisions aligned with project objectives. The initial project schedule is developed using standard project management tools (e.g., Gantt charts, CPM/PERT). However, to assess its robustness under uncertainty, Monte Carlo simulation is applied. This simulation evaluates the impact of variability in task durations and resource availability, generating a probabilistic distribution of possible project outcomes.

Once the probabilistic assessment is complete, pre-control charts are designed based on expected values and control thresholds. Inspired by industrial quality control methods, these charts categorize scheduling performance into three zones: acceptable (Green), warning (Yellow), and action-required (Red). During the project execution phase, monthly monitoring is conducted. Actual progress is compared against pre-control charts. If deviations exceed predefined thresholds, a feedback mechanism triggers schedule revision procedures. This ensures dynamic adaptation rather than static adherence to initial plans. The schedule revision algorithm includes both corrective (Short-term) and preventive (Strategic) actions. For example, reallocation of resources or resequencing of tasks might be initiated depending on the deviation pattern detected.

This method provides both scientific rigor and practical flexibility, allowing project teams to manage uncertainty, improve visibility, and align project execution with strategic goals. The approach is especially suited for complex or dynamic project environments where traditional baseline scheduling is insufficient. Software tools used in this methodology include simulation platforms (e.g., @Risk, Simul8) and project control systems (e.g., Primavera, MS Project), allowing seamless integration of simulation outputs with real-time project data. The proposed methodology is implemented through the following algorithmic steps:

Establish the project duration objective (Target duration and acceptable variance)

Considering the project's definition and the criticality of completing it within a specific timeframe, it becomes evident that one of the most vital parameters to control is the project's duration. In this phase, the acceptable time for project completion, along with the permissible variance, is determined based on the project documentation.

Establish the pre-control chart and duration zones for the project

Pre-control, often referred to as stoplight control, categorizes test units into three groups (Green, yellow, or red), as illustrated in *Fig. 2*. The decision to stop and make process adjustments is determined by the number of units falling into each of these color categories, as observed in a small sample. Since its inception, at least three distinct versions of pre-control have been proposed. This section focuses on the classical, two-stage, and modified versions [17]. In the pre-control chart, the areas above the USL and below the LSL are designated as the red zone, while the interval between them is referred to as the: "nominal size ± 1⁄4× total tolerance" are called the green zone, and regions between the red and green zones are called the yellow zone.

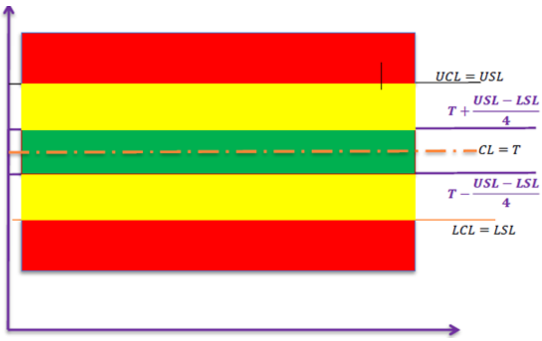

Fig. 2. Pre-control calculation and monitoring.

Project schedule simulation using Monte Carlo techniques

Monte Carlo simulation encompasses "any technique of statistical sampling employed to approximate solutions to quantitative problems" [18].

Monte Carlo simulation, also known as probability simulation, is a methodology employed to assess the impact of risk and uncertainty in various models, including financial, project management, cost, and forecasting models. In a Monte Carlo simulation, a random value is chosen for each task, guided by the estimated range. The model is then computed using this random value, and the outcome is recorded.

This process is iterated numerous times, typically hundreds or thousands, with different randomly selected values each time. Upon completing the simulation, a substantial number of model results are obtained, each based on different sets of random input values. These results are utilized to determine the likelihood or probability of achieving various outcomes within the model [19].

Step-by-step execution of project simulation model and plotting project duration on the pre-control chart

Given the inherent uncertainties related to time, resources, and project costs, this phase involves utilizing statistical techniques and probability density functions to derive various parameters for project activities. Subsequently, all activities, along with their associated risks, are input into Pert master software for project risk scheduling. Additionally, the project duration is determined for each run and plotted on the Pre-control chart.

The software-based project scheduling is carried out in accordance with the following criteria:

I. Activity descriptions are listed in the "description" column.

II. Uncertain activity durations are specified in the "duration uncertainty" column.

III. Contingency actions in response to events are documented under the "existence risk" category.

IV. The number of system runs for the risk analysis command is determined.

This meticulous process allows for a comprehensive evaluation of project durations and their associated uncertainties, aiding in effective project planning and control.

Adjusting the project schedule and demonstrating progress using the pre-control chart

The project scheduling simulation model is implemented step by step to track the progress of project completion time and is displayed on the Pre-control chart according to the following rules:

I. If five consecutive points fall within the green zone, it signifies that the project is on schedule and ready for implementation.

II. If the project duration, as determined by the simulation model, falls into the yellow zone, a full review is initiated, and project scheduling adjustments are necessary to ensure the project remains on track.

III. In cases where two instances of project duration within the simulation model fall within the yellow zone or the entire project duration falls within the red zone, a thorough project rescheduling is carried out, and the process is repeated.

IV. The confirmation of adherence to the schedule is achieved when five consecutive completion times, as determined by the simulation model, fall within the green zone.

These rules guide the adjustment of the project schedule and enable effective monitoring of project progress through the Pre-control chart, ensuring that the project remains on course and deviations are promptly addressed.

Controlling the project using the pre-control chart on a monthly basis

After each monthly update, the program is approved and executed, and the Pre-control chart is used to control the project according to the following rules:

I. If, upon the initial execution of the project's simulation model for the month, the results fall within the green zone without requiring any program adjustments, the project implementation proceeds as planned.

II. If, during the first execution of the project's simulation model for the month, the results indicate that the project is in the red zone, it becomes imperative to halt the project, review the program, and make necessary revisions before continuing the implementation. It is essential to ensure that this revised program aligns with legal requirements before proceeding. in the event that, upon the first execution of the project's simulation model for the month, the results fall within the yellow zone, a second round of simulation modeling is conducted to determine the latter part of the project's completion time.

III. if the results of this second run place the project within the green zone, the program proceeds without requiring any adjustments. however, if the project remains outside the green zone, it necessitates a review of the project schedule and the development of a new revision for continued project implementation.

These rules facilitate regular project monitoring and adjustments based on the pre-control chart, ensuring that the project remains on track and responsive to changing conditions.

All the above steps of the methodology are shown in *Fig. 3* and *Fig. 4*.

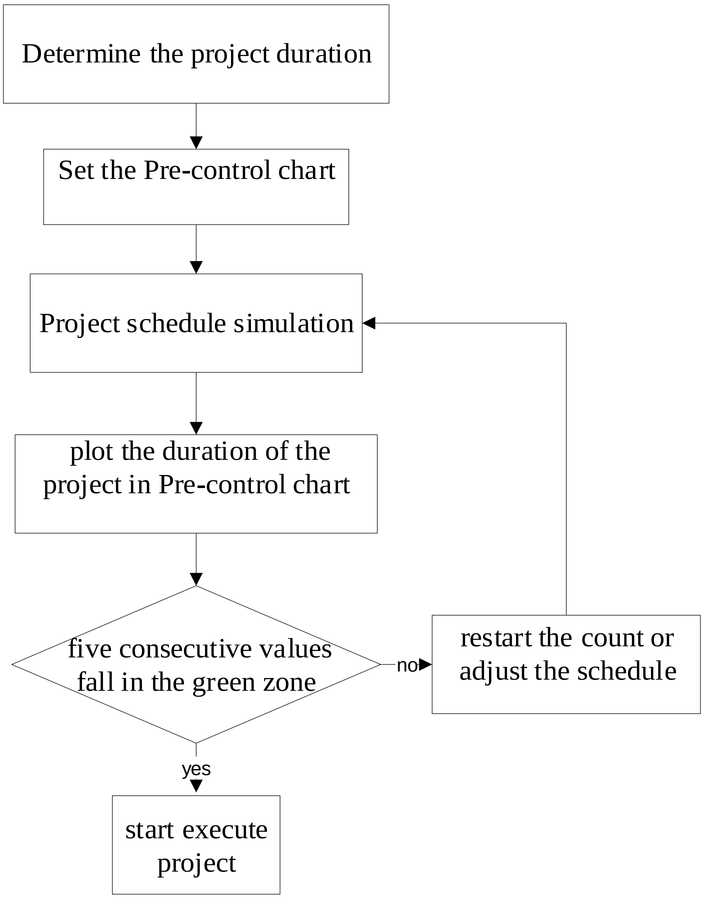

Fig. 3. Project scheduling set up.

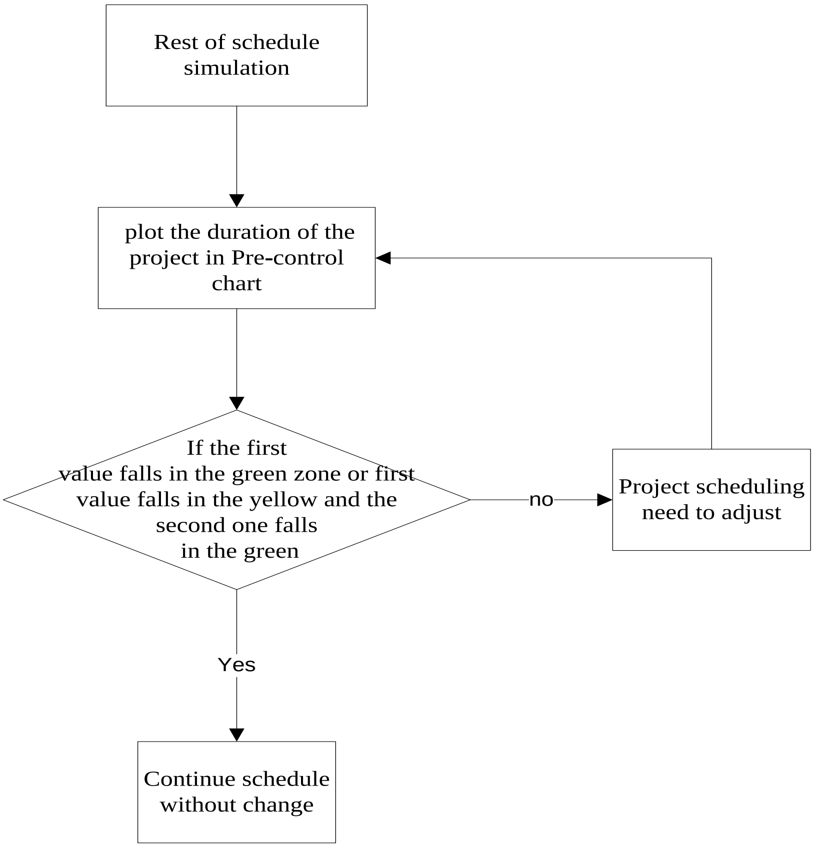

Fig. 4. Project scheduling control.

Illustration

For example, a project team wants to landscape a garden. They want to erect a fence, put in a pond, and lay a path. The project should be finished in two weeks. Tasks, minimum, most likely, maximum durations, relationship, and initial schedule are shown in the table.

Table 1. Activity list.

ID	Description	Remaining Duration	Remaining Cost	Distribution	Minimum Duration	Most Likely	Maximum Duration
0170	Total-Garden-project	14	840$				
0000	Start project	0					
0010	Garden Path	9	300$				
0020	Buy path materials	1	120$	Triangle	1	1	2
0030	Prepare ground	3	90$	Triangle	2	3	6
0040	Laypath	3	90$	Triangle	2	3	5
0050	FENCE	13	430$				
0060	Buy fence materials	1	130$	Triangle	1	1	2
0070	Dig post holes	2	60$	Triangle	1	2	4
0080	Put up posts	3	90$	Triangle	2	3	5
0090	Fix horizontals	3	90$	Triangle	2	3	5
0100	Paint fence	2	60$	Triangle	1	2	4
0110	Garden Pond	10	110$				
0120	Dig pond	3	90$	Triangle	2	3	5
0130	Line pond	2		Triangle	1	2	4
0140	Fill pond	2		Triangle	1	2	4
0150	Buyfish	1	20$	Triangle	1	1	2
0160	Ready for competition	0				0160	Ready for competition
Totals			840$				

Under the new proposed algorithms for planning and controlling projects, we follow these steps:

I. Determine the duration purpose of the project: The aim of the project in this example is 14 days, and variance to 4 days.

II. Set the pre-control chart and zones: In this example, the pre-control chart is set as follows (The results are shown in *Fig. 5*):

- *The center line of the chart is located at the nominal size (14 days).*
- *Horizontal lines are drawn at the USL (18) and the LSL (10).*
- *In addition, horizontal lines are also drawn at: "nominal size ± 1⁄4× (USL – LSL)." In our illustration, these lines are at: 14-1⁄4× (18 – 10) = 12 and 14 + 1⁄4× (18 – 10) = 16.*

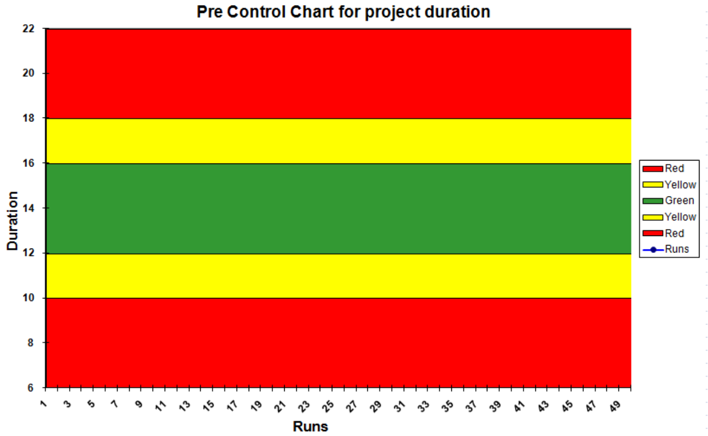

Fig. 5. Pre-control result of the illustration.

III. The project schedule simulation using Monte Carlo techniques: In this example, the Monte Carlo simulation model is as follows (*Fig. 6*):

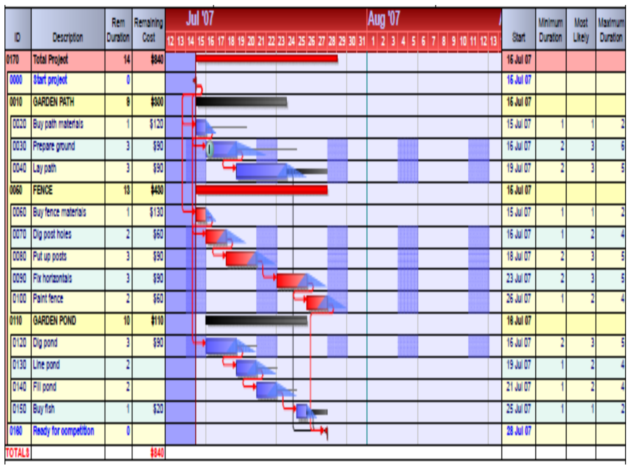

Fig. 6. Monte Carlo simulation model.

IV. Execution of the simulation model project step by step and plot the duration of the project in the Pre-control chart. In the first run, the scheduling simulation project duration is equal to 21 (*Fig. 7*).

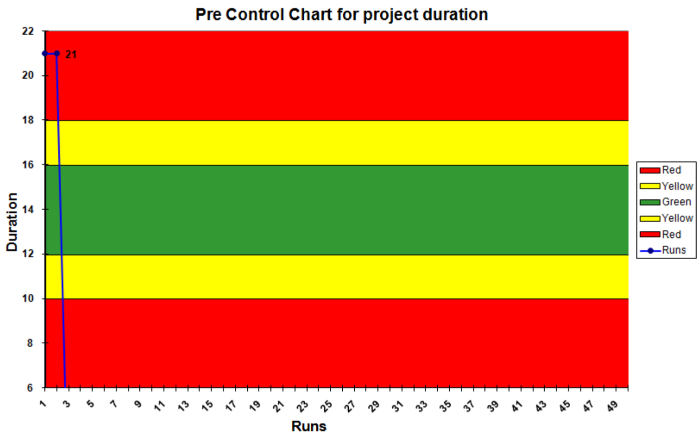

Fig. 7. Plot of first data.

The point is in the Red Zone, and it becomes clear that the program is required to Adjust. Therefore, calendar source labor, from 5 to 7 working day working day becomes. The simulation program is as follows (*Fig. 8*):

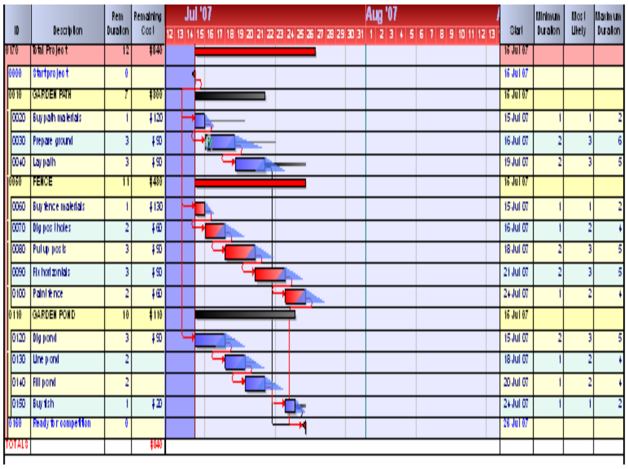

Fig. 8. Simulation program.

Run back to the project schedule simulation model, points 14, 13, 12, 15, and 14 are obtained (*Fig. 9*).

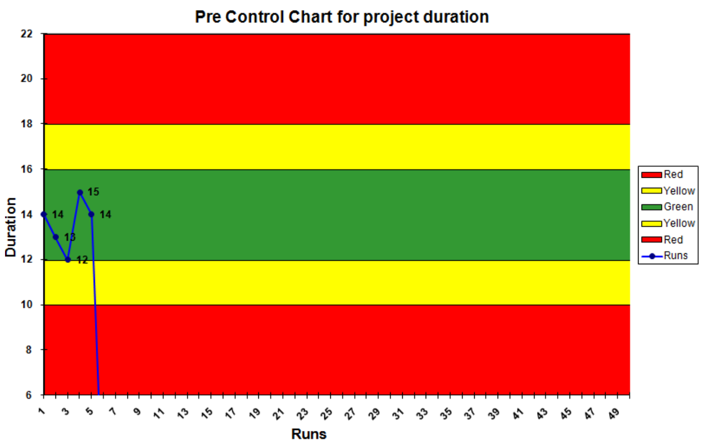

Fig. 9. Running back to the project schedule simulation model.

V. Adjust the project schedule: According to the pre-control chart, the project completion time points obtained from the previous stage, which takes place entirely in the green zone and is characterized by a schedule for the project that appropriate to refer to the implementation unit of the project.

4 | Conclusion

This study addresses a fundamental and often underexplored challenge in project management: the need for a structured and data-informed methodology for schedule formulation and time allocation for revisions prior to the commencement of project execution. To tackle this issue, a novel hybrid approach was proposed, which integrates Monte Carlo simulation techniques with pre-control chart tools, supported by the analytical capabilities of Primavera risk analysis software. This integration enables a more accurate, dynamic, and visual method of project planning and control, capable of managing uncertainty and facilitating proactive decision-making. The main contribution of this research lies in the adaptation of SPC tools—originally designed for industrial quality control—to the context of project planning and monitoring. By defining control zones (Green, yellow, red) and applying pre-control chart logic to the project schedule, the methodology offers project managers a visual and intuitive mechanism for:

I. Identifying deviations from the plan before they escalate

II. Structuring appropriate control periods

III. Allowing time for revision loops and corrective actions

IV. Enhancing transparency and communication across stakeholders

In operational terms, the approach helps manage uncertain parameters through probabilistic modeling, provides an algorithm for pre-implementation schedule adjustment, and evaluates the appropriateness of monitoring intervals using control zone feedback. Furthermore, it allows for a graphical demonstration of program effectiveness, making quality and performance visible and traceable throughout the planning process. The practicality and effectiveness of the method were illustrated through an applied example, demonstrating how this integrated approach can improve project readiness, reduce the risk of unanticipated delays, and strengthen alignment with overall project objectives.

This research sets the stage for future work in multiple directions. Notably, the extension of this methodology to multivariate pre-control charts presents an opportunity to concurrently monitor and adjust not only time-related factors but also cost and quality performance indicators. Such advancements could pave the way for multi-objective project control frameworks, where time, cost, and quality are managed within a unified, statistically robust, and easy-to-implement system. In conclusion, this paper contributes a simple yet scientifically rigorous method to the field of project management—one that merges stochastic analysis with real-time control logic. The resulting model supports more adaptive, transparent, and successful project execution, particularly in environments characterized by high variability and complex interdependencies.

Conflict of Interest

The authors declare no competing interests.

Data Availability

The datasets generated and analyzed during this study are available from the corresponding author upon reasonable request.

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