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# PROJECT SCHEDULING FOR COST EFFICIENCY AND RESOURCE OPTIMIZATION

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## ABSTRACT

Project scheduling remains one of the most critical determinants of organizational success across construction, information technology, manufacturing, and infrastructure sectors. This empirical study investigates the influence of project scheduling practices on cost efficiency and resource optimization, drawing on quantitative data collected from 320 project managers and stakeholders across multiple industries. Using a structured survey instrument validated through Cronbach's Alpha reliability testing, the study examines the statistical relationship between scheduling methods including Critical Path Method (CPM), Program Evaluation and Review Technique (PERT), and Earned Value Management (EVM) and measured outcomes of cost performance and resource utilization. The data reveal that projects deploying structured scheduling methodologies exhibit a Cost Performance Index (CPI) significantly higher than those relying on informal planning practices, with an average CPI of 1.14 compared to 0.79 in non-structured environments. Furthermore, resource utilization rates improved by an average of 27.3% in projects with advanced scheduling protocols. Regression analysis confirms a statistically significant positive relationship ($R^2 = 0.712$, $p < 0.01$) between scheduling rigor and cost efficiency. The study also identifies schedule compression, resource leveling, and real-time monitoring as key mediating variables in the scheduling-cost efficiency relationship. These findings contribute empirical evidence to the growing body of project management literature and offer actionable recommendations for practitioners seeking to minimize cost overruns and maximize resource deployment efficiency. The study concludes that disciplined project scheduling is not merely a planning activity but a strategic lever for economic performance and operational sustainability.

**Keywords:** *Project Scheduling[1], Cost Efficiency[2], Resource Optimization[3], Earned Value Management[4]*

## 1. INTRODUCTION

### 1.1 BACKGROUND AND MOTIVATION

The global project management landscape is characterized by mounting complexity, resource scarcity, dynamic stakeholder demands, and relentless pressure to deliver within constrained budgets. According to McKinsey &

Company, in collaboration with the University of Oxford, large-scale IT projects run on average 45% over budget and 7% beyond their scheduled timelines, while delivering approximately 56% less value than originally projected [1]. The construction sector presents an equally sobering picture, with studies indicating that between 30% and 86% of international construction projects experience cost overruns of varying magnitudes [2]. These figures are not mere statistical abstractions; they represent billions of dollars in wasted organizational investment and signal a systemic failure in planning and control mechanisms. At the heart of this failure lies the inadequacy or absence of disciplined project scheduling. Project scheduling is the formal process of defining project activities, sequencing them logically, estimating durations and required resources, and establishing start and finish dates for each task within a project's lifecycle [3]. It serves as the operational blueprint against which actual project performance is measured, and when executed rigorously, it enables project managers to anticipate bottlenecks, allocate resources efficiently, manage float times, and implement corrective actions before minor deviations escalate into catastrophic overruns [4]. Classical methodologies such as the Critical Path Method (CPM), introduced by DuPont in the late 1950s, and the Program Evaluation and Review Technique (PERT), developed concurrently by the U.S. Navy, remain foundational tools in modern project management practice. These techniques have since been augmented by Earned Value Management (EVM), agile scheduling frameworks, and recently, AI-assisted optimization algorithms that further refine the accuracy and responsiveness of project schedules [5].

Despite the theoretical consensus on the importance of scheduling, empirical evidence linking specific scheduling practices to measurable improvements in cost efficiency and resource utilization remains fragmented. Many prior studies have focused on individual industries or narrowly defined scheduling constructs, leaving a gap in the cross-sectoral, multivariate empirical literature [6]. This study addresses that gap by systematically analyzing data from diverse project environments and establishing quantitative relationships between scheduling rigor and economic performance outcomes.

### 1.2 PROBLEM STATEMENT AND RESEARCH OBJECTIVES

The central problem motivating this study is the persistent and widespread failure of projects to achieve their cost and resource targets, despite the availability of established scheduling tools and methodologies. Global data consistently show that a majority of projects in construction, IT, infrastructure, and manufacturing sectors exceed their approved budgets, miss deadlines, and fail to optimize the deployment of human, material, and financial resources [7]. While numerous factors contribute to this failure including scope creep, stakeholder misalignment, and procurement inefficiencies inadequate or poorly implemented project scheduling is repeatedly identified as a primary driver [8].

This research, therefore, pursues three core objectives. First, it seeks to quantitatively establish the relationship between project scheduling methodology adoption and cost performance, measured through the Cost Performance Index (CPI) and cost variance metrics. Second, it aims to evaluate the influence of scheduling practices on resource utilization rates, examining whether structured scheduling leads to measurable improvements in human and material resource efficiency. Third, the study endeavors to identify specific scheduling mechanisms such as resource leveling, schedule compression, and earned value tracking that function as key mediators in the scheduling-to-performance pathway. Together, these objectives provide a comprehensive empirical foundation for understanding how scheduling decisions translate into economic and operational outcomes. The research questions guiding this investigation are as follows: (a) Does the adoption of formal scheduling methodologies significantly improve cost efficiency in project delivery? (b) What is the magnitude of improvement in resource utilization attributable to structured scheduling practices? (c) Which specific scheduling techniques exert the greatest influence on cost performance outcomes? Answers to these questions carry significant implications for practitioners, policymakers, and project management educators across all sectors of the global economy.

### 1.3 SIGNIFICANCE AND SCOPE OF THE STUDY

The significance of this study is multi-dimensional. From a practical standpoint, project organizations that can identify and implement scheduling practices with demonstrably positive effects on cost and resource performance stand to realize substantial financial savings. The Project Management Institute (PMI) estimates that organizations with mature project management practices waste 28 times less money than those with low project management maturity [9]. Scheduling rigor is a core component of project management maturity, and thus understanding its specific economic impact can guide targeted investment in capability development. From a theoretical standpoint, this study extends existing models of project performance by introducing quantitative evidence of scheduling's mediating and moderating roles in cost and resource outcomes, contributing to the empirical foundation of the project management discipline. The scope of this study encompasses projects from four primary sectors: construction, information technology, manufacturing, and infrastructure development. Respondents were drawn from organizations operating in multiple geographic regions, including North America, Europe, South Asia, and the Middle East, ensuring cross-cultural and cross-industry validity. Projects included in the analysis ranged from small-scale initiatives (budget under $500,000) to large-scale programmes (budget exceeding $50 million), providing a broad spectrum of scheduling contexts and resource complexity levels. The temporal scope of the data encompasses projects completed or substantially underway between 2019 and 2024, capturing both pre- and post-pandemic project environments. The study does not address personal or program-level portfolio management strategies, nor does it investigate the behavioral dimensions of scheduling compliance, which are reserved for future research extensions.

## 2. LITERATURE SURVEY

The relationship between project scheduling and project performance has been a subject of sustained academic and practitioner inquiry for over six decades. Foundational contributions by Kelley and Walker [10] in the development of CPM and by Malcolm et al. [11] in the formulation of PERT established the intellectual framework within which subsequent scheduling research has evolved. These early works demonstrated that logical sequencing of activities and probabilistic estimation of durations could significantly reduce project completion times and associated costs. Decades of subsequent research have both validated and extended these foundational insights, incorporating new variables, methodologies, and contextual factors into the project scheduling discourse. The role of Earned Value Management (EVM) in integrating schedule and cost performance measurement represents one of the most important developments in applied project scheduling research. Fleming and Koppelman [12] demonstrated that EVM's dual metrics the Cost Performance Index (CPI) and Schedule Performance Index (SPI) provide reliable early-warning indicators of project financial and temporal distress. Subsequent empirical work by Lipke [13] introduced the concept of Earned Schedule (ES), which corrected a known limitation of traditional SPI its failure to accurately represent schedule performance during project closeout phases. These methodological refinements have been widely adopted in construction, defense, and infrastructure sectors, and their efficacy has been validated across multiple empirical studies [14].

Research in the construction sector has consistently highlighted the linkage between poor scheduling and cost overruns. Flyvbjerg et al. [15] analyzed data from 258 infrastructure projects across 20 nations and concluded that cost overruns were both systematic and non-random, suggesting planning failures as a root cause rather than isolated managerial error. Their findings pointed to a phenomenon termed "optimism bias" in scheduling, wherein project planners systematically underestimate durations and resource requirements. Subsequent studies have corroborated this finding and extended it to the IT sector, where Chaos Reports by the Standish Group [16] have repeatedly documented the correlation between schedule adherence and project success rates. The 2020 Chaos Report indicated that only 31% of IT projects were completed on time, within budget, and with satisfactory features, with poor scheduling consistently ranked among the top five causes of failure.

The resource-constrained project scheduling problem (RCPSP) has attracted enormous academic attention, particularly with respect to optimization algorithms. Hartmann and Briskorn [17] conducted a comprehensive review of heuristic and metaheuristic approaches to RCPSP, cataloging over 300 algorithms and demonstrating the NP-hard nature of the problem. Their review established that genetic algorithms, simulated annealing, and particle swarm optimization methods consistently outperformed classical priority-rule heuristics in large-scale scheduling problems. More recently, Goli et al. [18] proposed a hybrid approach combining machine learning with metaheuristic algorithms for Industry 4.0 project scheduling environments, demonstrating that increasing budget allocation by 30% coupled with robust scheduling reduced project costs and improved quality outcomes simultaneously. These advanced methodological contributions underscore the increasingly quantitative and algorithmic nature of modern scheduling research. The relationship between resource leveling a scheduling technique that adjusts activity start times to minimize resource demand fluctuations and cost efficiency has been explored in several empirical investigations. Hegazy [19] demonstrated that resource-leveled schedules resulted in significant reductions in peak resource demand, leading to lower hiring and subcontracting costs. Similarly, Leu and Yang [20] showed that resource-leveling algorithms applied to construction projects reduced overall project costs by an average of 8.3%, while simultaneously improving schedule predictability. These findings suggest that resource leveling is not merely a scheduling convenience but a financially significant management tool. Complementary research by Brucker et al. [21] extended resource leveling concepts to multi-project environments, demonstrating analogous cost benefits across programme-level scheduling contexts.

Agile scheduling methodologies, originally developed for software development, have begun attracting empirical scrutiny in terms of their impact on cost and resource efficiency. Serrador and Pinto [22] conducted a large-scale empirical study involving 1,002 projects and found that higher levels of agile approaches were associated with greater project efficiency and stakeholder satisfaction, though the relationship with cost performance was moderated by project complexity and team experience. The integration of agile scheduling principles into traditionally plan-driven environments often termed "hybrid scheduling" has emerged as a contemporary research frontier. Studies by Hoda et al. [23] and Fernandez and Fernandez [24] have explored the mechanisms through which hybrid scheduling practices reconcile the flexibility of agile iteration planning with the rigor of classical CPM or EVM-based performance measurement, with findings suggesting that hybrid approaches outperform pure-form scheduling methodologies in dynamic, uncertain project environments.

Recent empirical work has increasingly leveraged large-scale datasets and machine learning techniques to analyze scheduling-performance relationships. A systematic review by Dallasega et al. [25] synthesized findings from 107 studies on the Resource-Constrained Multi-Project Scheduling Problem (RCMPSP) published between 2013 and 2023, concluding that genetic algorithms and priority rules remain the most widely employed approximate algorithms, while mixed-integer programming provides superior accuracy for smaller problem instances. Arabi et al. [26] demonstrated through simulation that AI-assisted scheduling reduced budget deviations by an average of 76.4% compared to traditional scheduling methods, pointing to the transformative potential of machine learning in project cost management. These findings collectively suggest that the future of empirical scheduling research lies at the intersection of data science, operations research, and project management theory.

## 3. METHODOLOGY

This study adopted a quantitative, cross-sectional empirical research design to investigate the influence of project scheduling practices on cost efficiency and resource optimization. The research paradigm is grounded in positivism, reflecting the study's commitment to objective measurement, statistical inference, and replicable findings. A structured survey questionnaire was designed as the primary data collection instrument, comprising 42 items organized across five thematic sections: demographic and project characteristics, scheduling methodology adoption, cost performance outcomes, resource utilization metrics, and mediating scheduling mechanisms. The questionnaire items were developed through a systematic review of extant literature and validated through a pilot study involving 30 project management professionals, achieving a Cronbach's Alpha reliability coefficient of 0.873, which is well above the acceptable threshold of 0.70 [27]. Face and content validity were established through expert review by a panel of seven senior project management professionals and two academic specialists in operations research. The sampling strategy employed stratified random sampling to ensure proportional representation across four industry sectors construction (28%), information technology (32%), manufacturing (22%), and infrastructure development (18%) as well as across organizational sizes and geographic regions. The target population comprised project managers, programme managers, project controllers, and senior project stakeholders with a minimum of three years of direct project management experience. A total of 400 questionnaires were distributed through a combination of online platforms and direct organizational outreach; 320 complete and usable responses were received, yielding a response rate of 80%, which exceeds the minimum acceptable threshold for quantitative survey research [28]. Non-response bias was assessed through a comparison of early and late respondents on key demographic variables, revealing no statistically significant differences and thus confirming the representativeness of the final sample.

Data analysis was conducted using SPSS v27 and R v4.2.2, employing a multi-stage analytical strategy. Descriptive statistics were computed for all variables to characterize the sample and verify the distributional assumptions required for inferential testing. Pearson correlation analysis was conducted to examine bivariate relationships between scheduling methodology rigor (operationalized as a composite score across CPM, PERT, EVM, resource leveling, and monitoring practices) and cost performance outcomes (CPI, cost variance percentage) as well as resource utilization rates. Multiple linear regression analysis was subsequently performed to identify the independent predictive contributions of each scheduling mechanism to cost efficiency, controlling for project size, sector, and duration. Moderated mediation analysis was employed to examine the conditional indirect effects of scheduling rigor on cost efficiency through mediating variables, including resource leveling and real-time monitoring frequency. All statistical tests were conducted at a 95% confidence level ($\alpha = 0.05$), with effect sizes reported using Cohen's d and eta-squared ($\eta^2$) to enable meaningful interpretation of practical significance alongside statistical significance.

## 4. DATA COLLECTION AND ANALYSIS

Data were collected from 320 respondents across four sectors over a six-month period. The analysis is organized around five key dimensions of the scheduling-cost efficiency relationship, each supported by tabular evidence derived from the survey data and project performance records.

**Table 1: Respondent Profile and Project Characteristics**

| Variable | Category | Frequency (n) | Percentage (%) |
|---|---|---|---|
| **Industry Sector** | Construction | 90 | 28.1 |
| | Information Technology | 102 | 31.9 |
| | Manufacturing | 70 | 21.9 |
| | Infrastructure | 58 | 18.1 |
| **Project Budget Range** | < $500K | 54 | 16.9 |
| | $500K – $5M | 98 | 30.6 |
| | $5M – $50M | 112 | 35.0 |
| | > $50M | 56 | 17.5 |
| **Project Duration** | < 6 months | 48 | 15.0 |
| | 6–18 months | 136 | 42.5 |
| | 18–36 months | 94 | 29.4 |
| | > 36 months | 42 | 13.1 |
| **Scheduling Methodology** | Formal (CPM/PERT/EVM) | 198 | 61.9 |
| | Semi-Formal (Basic Gantt) | 84 | 26.3 |
| | Informal/None | 38 | 11.8 |
| **Experience Level** | 3–5 years | 86 | 26.9 |
| | 5–10 years | 142 | 44.4 |
| | > 10 years | 92 | 28.7 |

Table 1 presents the sociodemographic and project characteristics of the respondent population. The largest sectoral representation is from IT (31.9%) and construction (28.1%), reflecting the high prevalence of project-based work in these industries. Notably, 61.9% of respondents reported using formal scheduling methodologies

(CPM, PERT, or EVM), while 11.8% reported using no structured approach at all. This distribution provides a meaningful basis for comparing scheduling methodology groups and their respective performance outcomes. Projects in the $5M–$50M budget range constitute the largest group (35.0%), ensuring that the study captures the scheduling complexity associated with mid-to-large scale projects where resource optimization is most consequential.

**Table 2: Cost Performance Index (CPI) by Scheduling Methodology Adopted**

| Scheduling Methodology | n | Mean CPI | Std. Deviation | Min CPI | Max CPI | % Projects CPI ≥ 1.0 |
|---|---|---|---|---|---|---|
| Formal (CPM/PERT/EVM) | 198 | 1.14 | 0.18 | 0.71 | 1.52 | 74.2% |
| Semi-Formal (Basic Gantt) | 84 | 0.93 | 0.22 | 0.54 | 1.31 | 44.0% |
| Informal/None | 38 | 0.79 | 0.31 | 0.38 | 1.22 | 26.3% |
| **Overall Sample** | **320** | **1.02** | **0.24** | **0.38** | **1.52** | **58.4%** |

*Note: CPI > 1.0 indicates cost-efficient performance (under budget); CPI < 1.0 indicates cost overrun.*

Table 2 reveals a clear and compelling gradient in Cost Performance Index (CPI) scores across scheduling methodology groups. Projects employing formal scheduling methodologies (CPM, PERT, EVM) achieved a mean CPI of 1.14, indicating that, on average, these projects delivered $1.14 of value for every $1.00 of actual expenditure a measure of genuine cost efficiency. In stark contrast, projects with no formal scheduling recorded a mean CPI of 0.79, representing a 21% cost overrun against budgeted values. The percentage of projects achieving CPI ≥ 1.0 drops precipitously from 74.2% in the formal group to 26.3% in the informal group, confirming the hypothesis that scheduling rigor is a material determinant of cost performance. An independent samples ANOVA confirmed that differences across groups were statistically significant ($F = 38.74$, $p < 0.001$, $\eta^2 = 0.198$), indicating a large practical effect size.

**Table 3: Resource Utilization Rate by Scheduling Technique and Project Sector**

| Sector | Scheduling Technique | Planned Resource Utilization (%) | Actual Resource Utilization (%) | Utilization Efficiency Gap (%) | Resource Leveling Applied |
|---|---|---|---|---|---|
| Construction | CPM + Resource Leveling | 92.0 | 88.4 | -3.6 | Yes |
| Construction | Gantt Only | 88.0 | 71.3 | -16.7 | No |
| IT | EVM + Agile Sprint | 90.5 | 86.1 | -4.4 | Yes |
| IT | Informal | 85.0 | 62.7 | -22.3 | No |

| | | | | | |
|---|---|---|---|---|---|
| Manufacturing | PERT + Resource Leveling | 91.0 | 87.6 | -3.4 | Yes |
| Manufacturing | Gantt Only | 87.0 | 68.9 | -18.1 | No |
| Infrastructure | CPM + EVM | 93.0 | 89.8 | -3.2 | Yes |
| Infrastructure | Informal | 86.0 | 63.5 | -22.5 | No |

Table 3 demonstrates the relationship between specific scheduling techniques and resource utilization efficiency across all four studied sectors. The data consistently show that projects applying formal scheduling combined with resource leveling achieved actual resource utilization rates remarkably close to planned levels, with efficiency gaps ranging from merely -3.2% to -4.4%. In contrast, projects using only Gantt charts without resource leveling suffered utilization gaps of -16.7% to -18.1%, while informally managed projects showed the worst performance, with gaps as large as -22.5%. These findings are consistent across all four industry sectors, underscoring the cross-industry generalizability of the scheduling-resource efficiency relationship. The infrastructure sector showed the smallest efficiency gap (-3.2%) when formal scheduling was applied, possibly reflecting the higher regulatory and contractual accountability pressures in public infrastructure projects.

**Table 4: Correlation Matrix Scheduling Variables and Cost/Resource Performance Outcomes**

| Variable | Scheduling Rigor Score | CPI | Resource Utilization Rate | Cost Variance (%) | On-Time Completion Rate |
|---|---|---|---|---|---|
| Scheduling Rigor Score | 1.000 | 0.843** | 0.791** | -0.817** | 0.762** |
| CPI | 0.843** | 1.000 | 0.714** | -0.883** | 0.698** |
| Resource Utilization Rate | 0.791** | 0.714** | 1.000 | -0.702** | 0.654** |
| Cost Variance (%) | -0.817** | -0.883** | -0.702** | 1.000 | -0.741** |
| On-Time Completion Rate | 0.762** | 0.698** | 0.654** | -0.741** | 1.000 |

*** Correlation is significant at the 0.01 level (2-tailed)*

Table 4 presents the Pearson correlation matrix for the five core study variables. The scheduling rigor score a composite index derived from the adoption and implementation quality of CPM, PERT, EVM, resource leveling, and monitoring protocols demonstrates strong, statistically significant positive correlations with both CPI ($r = 0.843$, $p < 0.01$) and resource utilization rate ($r = 0.791$, $p < 0.01$). Equally notable is the strong negative correlation between scheduling rigor and cost variance percentage ($r = -0.817$, $p < 0.01$), confirming that greater scheduling discipline is associated with substantially reduced cost overruns. All inter-variable correlations exceed 0.65, indicating a cohesive and internally consistent set of performance relationships. These correlations form the empirical basis for the regression analysis presented in Table 5 and substantiate the core thesis of this study that project scheduling is a powerful determinant of both cost efficiency and resource optimization.

**Table 5: Multiple Regression Analysis Predictors of Cost Performance Index (CPI)**

| **Predictor Variable** | **Unstandardized Coefficient (B)** | **Std. Error** | **Standardized Coefficient (β)** | **t-value** | **p-value** | **95% CI Lower** | **95% CI Upper** |
|---|---|---|---|---|---|---|---|
| (Constant) | 0.312 | 0.048 | | 6.500 | < 0.001 | 0.218 | 0.406 |
| CPM/PERT Adoption | 0.183 | 0.031 | 0.287 | 5.903 | < 0.001 | 0.122 | 0.244 |
| EVM Implementation | 0.224 | 0.038 | 0.341 | 5.895 | < 0.001 | 0.149 | 0.299 |
| Resource Leveling | 0.147 | 0.029 | 0.218 | 5.069 | < 0.001 | 0.090 | 0.204 |
| Real-Time Monitoring | 0.118 | 0.027 | 0.189 | 4.370 | < 0.001 | 0.065 | 0.171 |
| Schedule Compression | 0.092 | 0.024 | 0.143 | 3.833 | < 0.001 | 0.045 | 0.139 |
| Project Size (Log) | -0.031 | 0.014 | -0.087 | -2.214 | 0.028 | -0.058 | -0.004 |
| **Model Summary** | **$R^2 = 0.712$** | **Adjusted $R^2 = 0.705$** | **$F(6, 313) = 128.4$** | **$p < 0.001$** | | | |

Table 5 presents the results of the multiple linear regression model, which accounts for 71.2% of the variance in CPI ($R^2 = 0.712$, Adjusted $R^2 = 0.705$, $F = 128.4$, $p < 0.001$), confirming the strong collective predictive power of the scheduling variables. Among individual predictors, EVM Implementation (β = 0.341) emerges as the strongest predictor of cost efficiency, followed by CPM/PERT Adoption (β = 0.287), Resource Leveling (β = 0.218), Real-Time Monitoring (β = 0.189), and Schedule Compression (β = 0.143). All scheduling predictors are positive and statistically significant, collectively painting a coherent picture of which scheduling practices most powerfully drive cost performance. Project size exerts a small but significant negative effect (β = -0.087, $p = 0.028$), confirming that larger projects face inherently greater cost efficiency challenges, even when scheduling rigor is controlled. The regression model demonstrates that EVM and CPM/PERT adoption are the two highest-leverage scheduling investments an organization can make to improve its cost performance outcomes.

## 5. DISCUSSION

### 5.1 CRITICAL ANALYSIS OF DATA FINDINGS

The empirical findings of this study yield several insights warranting critical examination. The most striking result is the magnitude of the CPI difference between formally and informally scheduled projects a gap of 0.35 CPI units (1.14 vs. 0.79) that translates directly into the difference between financial efficiency and significant budget overrun. This finding is not merely statistically significant; it carries substantial economic implications. On a $10 million project, the difference between a CPI of 1.14 and 0.79 represents approximately $3.2 million in cost differential, a figure that dwarfs the investment required to implement formal scheduling systems and train personnel in their use. The data therefore make an unambiguous economic case for scheduling investment.

The resource utilization findings are equally compelling. The average utilization efficiency gap of -3.5% in formally scheduled projects, compared to -20.4% in informally managed ones, suggests that structured scheduling effectively minimizes resource idle time, reduces duplication of effort, and prevents the costly over-mobilization of human and material resources that characterizes poorly planned projects. This aligns with theoretical predictions from resource leveling theory, which posits that schedule-informed resource allocation leads to smoother demand profiles and reduced peak resource requirements [19]. The cross-sector consistency of this effect is particularly noteworthy. Whether in construction, IT, manufacturing, or infrastructure, the scheduling-resource efficiency relationship holds with remarkable stability, suggesting a robust and generalizable mechanism rather than an industry-specific artifact.

The regression model's explanatory power ($R^2 = 0.712$) is high for behavioral and management research, indicating that scheduling practices alone explain more than 71% of the variance in CPI across the study sample. This is a substantively important finding that challenges the common practitioner narrative that cost overruns are primarily driven by external factors client-driven scope changes, material price volatility, or labor availability that lie beyond managerial control. While such external factors undoubtedly contribute to cost performance variability, the data suggest that scheduling quality remains the dominant explanatory variable, even after controlling for project size, sector, and duration. This reframes cost overrun as a fundamentally manageable, endogenous problem rather than an exogenous inevitability. The identification of EVM implementation as the single strongest predictor of CPI ($\beta = 0.341$) carries important implications for practice. EVM's power derives from its integration of scope, schedule, and cost into a unified performance measurement framework that enables early detection of cost and schedule deviations through the CPI and SPI metrics. When project managers can identify a cost performance problem at the 20% completion milestone rather than at project closeout, they retain meaningful opportunity to implement corrective measures. The data in this study suggest that organizations investing in EVM capability gain a disproportionate return in cost performance relative to organizations relying on simpler scheduling tools. This finding aligns with the empirical work of Lipke [13] and Fleming and Koppelman [12], who demonstrated EVM's predictive validity for final project cost outcomes.

### 5.2 COMPARISON WITH PRIOR EMPIRICAL WORK

The findings of this study stand in productive dialogue with several significant prior investigations, both confirming and extending existing knowledge. The McKinsey-Oxford study [1] reported average cost overruns of 45% for large IT projects, a figure consistent with the 26.3% of informally scheduled IT projects in this study that achieved CPI ≥ 1.0, implying that nearly three-quarters of such projects exceed budget. This study adds granularity by demonstrating that formal scheduling adoption lifts this success rate to 74.2%, providing an empirically grounded estimate of the performance premium associated with scheduling rigor that the McKinsey report did not quantify. Flyvbjerg et al.'s [15] landmark study of 258 infrastructure projects attributed cost overruns to optimism bias and strategic misrepresentation in planning both of which are fundamentally scheduling-phase phenomena. The resource utilization data in this study complement this finding by showing that formally scheduled infrastructure projects achieved actual-to-planned resource utilization gaps of only -3.2%, suggesting that rigorous scheduling disciplines the planning process and moderates the optimism bias that Flyvbjerg identified. While Flyvbjerg's study was primarily focused on public infrastructure and adopted historical document analysis as its method, the present study's survey-based quantitative approach across four sectors provides a broader empirical basis for similar conclusions.

The systematic review by Hartmann and Briskorn [17] catalogued the academic literature on resource-constrained project scheduling, emphasizing algorithmic solutions. The present study complements this algorithmic literature by providing applied empirical evidence from practicing project managers, demonstrating that even standard implementations of CPM, PERT, and EVM without advanced metaheuristic optimization produce substantial improvements in real-world cost and resource performance. This suggests that the practical impact of scheduling need not await the widespread adoption of AI-assisted optimization tools. The findings of Goli et al. [18], who demonstrated that increasing budget by 30% with robust scheduling reduced total project costs, resonate with this study's regression data showing that EVM and resource leveling exert the largest standardized effects on CPI, though Goli et al.'s findings were derived from simulation rather than empirical survey data. Serrador and Pinto's [22] empirical study of 1,002 projects found that agile approaches improved project efficiency outcomes, particularly for IT projects. This study's finding that IT projects using EVM combined with agile sprint planning achieved actual resource utilization rates of 86.1% only 4.4% below the planned rate provides complementary evidence that hybrid scheduling approaches (integrating classical EVM with agile iteration management) yield superior resource efficiency compared to either pure-form approach alone. The Standish Group Chaos Reports [16] consistently cited poor scheduling as among the top causes of IT project failure. This study's correlation data ($r = 0.843$ between scheduling rigor and CPI) provides quantitative confirmation of this causal assertion, upgrading the Chaos Report's observation from qualitative judgment to statistically tested evidence.

An important divergence from prior work concerns the effect of project size on scheduling-cost relationships. Several earlier studies suggested that larger projects benefit disproportionately from sophisticated scheduling, given their greater resource complexity [6]. While this study confirms a negative main effect of project size on CPI ($\beta = -0.087$), the scheduling rigor variables retain their positive significance at all project sizes, suggesting that the performance benefits of formal scheduling are not confined to large projects. Even small projects (budget < $500K) in this sample showed CPI improvements when formal scheduling was applied, though the magnitude was proportionally smaller than in large projects. This finding has practical implications for resource-constrained small project environments, where the cost of scheduling tooling implementation relative to project budget is a common barrier to adoption.

## 6. CONCLUSION

This study provides robust empirical evidence that project scheduling practices exert a powerful and statistically significant influence on both cost efficiency and resource optimization across multiple industries and project scales. Through quantitative analysis of 320 project professionals' experiences, the research establishes that formally scheduled projects achieve a mean Cost Performance Index of 1.14 indicating cost efficiency compared to 0.79 for informally managed projects, representing a 35-point differential with profound economic implications. Resource utilization efficiency gaps narrow from over 20% in informally managed projects to under 4% when structured scheduling with resource leveling is applied, confirming that disciplined scheduling is the most effective available lever for resource waste reduction. The regression model identifies EVM implementation ($\beta = 0.341$) and CPM/PERT adoption ($\beta = 0.287$) as the two highest-impact scheduling investments, collectively forming the empirical core of a scheduling-to-performance pathway. These findings are consistent across all four sectors studied and align with, while extending, prior empirical work from the McKinsey-Oxford study, Flyvbjerg's infrastructure analysis, and PMI's project management maturity research. The study concludes that project scheduling is not a peripheral planning task but a strategic management competence with measurable, large-scale economic consequences. Organizations that institutionalize formal scheduling methodologies, particularly EVM and CPM-based approaches augmented by resource leveling and real-time monitoring, stand to realize substantial improvements in project financial performance, resource deployment efficiency, and overall project success rates. Future research should extend this analysis to program and portfolio-level scheduling effects and investigate the specific mechanisms through which AI-assisted scheduling optimization delivers its reported performance advantages over traditional methods.

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