# Influence of Cost Overruns on Risk Perception

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**Abstract**: Cost overruns are a common problem in project management and can significantly impact project outcomes. While previous research has focused on accurately estimating project risks, less attention has been paid to understanding the relationship between cost overruns and risk perception. This study aims to improve risk management practices by modeling the dynamic relationship between cost overruns and risk perception. Specifically, a project system is represented as a causal loop diagram that incorporates short- and long-term cost variances, work performed, and risk perception. The model shows that unmitigated short-term cost overruns can lead to long-term cost overruns and demonstrates how responses in the project monitoring system can mitigate this effect. By providing a basis for simulating the impact of responses to cost overruns, this study offers insights into how to improve risk management practices. The findings contribute to a better understanding of how risk perception influences decision-making in response to cost overruns and highlight the importance of proactive risk management strategies in project management.

**Keywords**: Project Management; Risk management; Project Monitoring, Risk Perception

## I. INTRODUCTION

Effective Project Risk Management practices play a crucial role in ensuring the success of complex projects [1–4]. Project Risk Management helps anticipate uncertainties, allowing for reactive measures through corrective actions or proactive measures to mitigate risks [5–6]. The significance of Project Risk Management increases according to the complexity of the projects due to the exacerbation of uncertainty and risks exposure that may jeopardize the accomplishment of the project goals [7–13]. To tackle these challenges, contingency plans used to be incorporated into the budget in the early planning stages [14]. These contingency accounts act as reserves purposely incorporated by project managers for funding threats mitigation that could potentially impact the project's objectives (i.e., time, quality, and cost) [15,16]. These accounts increase project managers' confidence that the project can be completed within the baseline cost, despite uncertainties throughout its lifecycle. An accurate estimation of contingency accounts is crucial in determining whether to develop a project, particularly when the client has a fixed budget [17].

While considerable progress has been achieved in project risk management, insufficient attention has been devoted to resource allocation to minimize and mitigate these risks [18]. Historically, literature focused on contingency management has centered its attention on estimating the maximum allowable spending based on project progress alone, disregarding other factors. However, this approach fails to consider that contingency management also depends on multiple additional factors such as the subjective perception of the project managers and project cost performance [19]. Although the significant research focused on analyzing contingency within the Project Risk Management literature, there remains a research gap in developing learning tools that allow project managers to understand the intricate relationships between project managers' perceptions, cost performance indicators, and uncertainty for enhancing contingency spending.

Contingency budgets literature has prioritized estimating these budgets through diverse methods such as synthetic neural networks [20] or quantitative models [14,15,21]. Nevertheless, effectively managing contingency needs further research to equip project managers with the necessary decision-making insights during project execution. Additionally, most of the research in contingency management lacks a systems approach that can expose intricate relationships among diverse drivers [7,14,19,22,23]. Moreover, the limited literature that integrates contingency management and a systems perspective fails to consider the influence of cost performance on contingency budget spending due to project managers’ perceptions [5].

This paper presents a System Dynamics contingency management model that exposes the relationship between risk response strategy, contingency reserve spending, cost performance, and project managers’ concern derived from this performance. The model differentiates short-term and long-term concerns for cost overruns derived from different parameters within Earned Value Method. The former results from the variance between incremental cost and earned value of work completed. Conversely, the latter indicates the difference between the cost estimate at completion and the available project budget including the remaining contingency.

## II. LITERATURE REVIEW

Project managers’ risk perception and response play a critical role in determining how and when the contingency budget should be spent [24]. This subjective risk perception is shaped by the organizational values and personal experiences of project managers [24,25]. As a result, project managers can deploy either a passive or aggressive contingency management strategy depending on their risk tolerance, namely, risk averter or risk-taker (Figure 1) [19,25,26]. A risk averter tends to deploy a passive strategy to postpone spending contingency budget at early stages based on an ad-hoc response to unexpected problems but as time passes the project manager is more prone to spend increasingly to meet critical objectives [19,25,26]. Conversely, a risk-taker tends to implement an aggressive strategy to use the contingency budget increasingly at early stages to solve unexpected events but once the contingency budget is significantly depleted its spending has to be restricted [19,25,26].

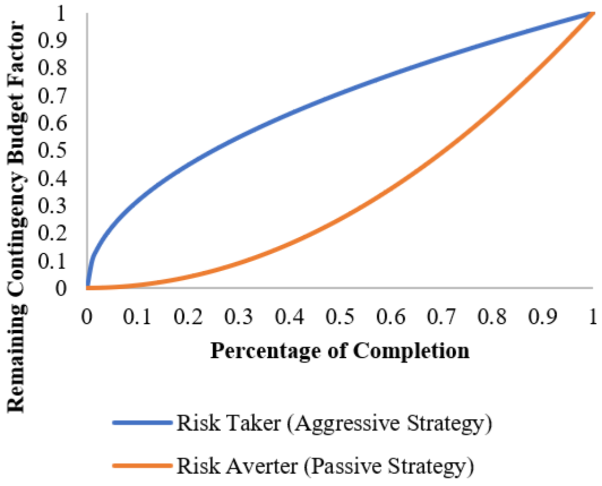


Figure 1. Contingency spending rate according to contingency management strategy

The global crisis that began in 2020 has highlighted the exacerbated exogenous risks affecting cost performance and project managers’ risk perception [27–29]. The pandemic-induced disruptions in the global supply chain have had a significant impact on inflation affecting projects worldwide [30,31]. These disruptions have led to heightened inflationary pressures due to the limited availability of specific components, technologies, and resources for projects globally [32]. The interconnectedness of economies through the global value chain has played a critical role in transmitting the effects of supply chain disruptions to prices [33]. The situation has been further exacerbated by the combination of demand and supply shocks, as well as the varying degrees of exposure to these shocks across industries [34]. Additionally, shipping costs have more than doubled compared to previous levels, contributing to higher product costs, and increasing inflation. Simultaneously, multiple countries are grappling with high inflation rates, which have implications for projects cost overruns and project managers’ risk perceptions on a global scale [32].

More recently, the conflict in Ukraine has resulted in heightened inflation and unprecedented price increases in crucial construction raw materials like steel. These developments have increased risks and underscored the importance of efficient contingency budget spending [26].

## III. METHODOLOGY

The model development process relied on the application of concepts associated with System

Dynamics as the overarching methodological framework [35]. The formulation of the model was derived from a comprehensive literature review. The aim of this model is to facilitate an understanding of how system behavior emerges from causal structures. It also helps identify the drivers that affect the project managers' decision-making on contingency budget spending, taking into account the project's cost performance, project managers' concerns derived from this performance, and risk responses.

The methodology encompasses multiple stages. Firstly, the relationship between risk response strategy, contingency reserve spending, cost performance, and project managers' concern derived from this performance was identified based on a literature review. Secondly, to visually represent the feedback structures that underlie the complex relationships determining the project managers' risk perception, a System Dynamics causal loop diagram was presented.

## IV. FINDINGS AND DISCUSSION

### *A. Causal loop diagram*

A qualitative representation of the system's interconnections, known as a Causal Loop Diagram, is developed to illustrate the causal relationships between variables through positive and negative links. Positive links indicate changes in the same direction between independent and dependent variables, while negative links represent opposite changes and can even include time delays [36]. The Causal Loop Diagram incorporates feedback loops, which can be either balancing (B) or reinforcing (R), connecting multiple dependent variables [37–41].

The proposed model is based on the following rationale. Project tasks are subject to risks that, if occurred, could lead to cost, time, and performance issues, which then translate into cost overruns, thus raising Project Managers' concerns about failing to meet the predetermined budget. This concern relates to both short-term and long-term cost overruns. Short-term cost overruns refer to the difference between the budgeted and actual cost of work performed in a given time frame, while long-term cost overruns refer to the difference between the estimated variance at completion and the available contingency reserve.

Risk responses involve using the contingency reserve to mitigate the Actual Cost ($AC$) may increase or reduce the Estimate at Completion ($EAC$). The response strategy is developed based on criteria that determine the frequency and amount to tap into the contingency reserve. Regarding the frequency, responses should be initiated whenever the Project Managers' concern for cost overruns exceeds a predetermined level. In determining the amount, several factors should be considered, including the amount of contingency reserve, how the project $EAC$ is evaluated, and the cost distribution and degree of correlation of project tasks.

After formulating the problem and planning the study, we define the simulation model by employing SD techniques.

Following the Earned Value Management methodology, the project system is represented in Figure 2 through a causal loop diagram (CLD) to describe the relationships and feedback structure between the monitoring variables.

The relationships between variables that compose the Causal Loop Diagram are described as follows. The simulation clock, denoted by the argument t, indicates the $t$h project review and ranges from time 0 (the project start) to PD (the project planned duration). At time t, the tasks performed determine the Marginal Work Performed, $dWP(t)$, which is related to the project Budget at Completion, BAC, to provide the Marginal Budgeted Cost of Work Performed, $dEV(t)$. On the other hand, $dWP(t)$ is also related to the Relative Cost Deviation factor, $x_i(t)$, to randomize the Marginal Actual Cost, dAC(t). The cumulative sum of $dEV(t)$ gives the accrued Earned Value, $EV(t)$, while the cumulative sum of dAC(t) gives the accrued Actual Cost, $AC(t)$. When $t = \text{PD}$, $EV(t)$ equals the project BAC, but $AC(\text{PD})$ can either be greater (cost overruns) or inferior (cost savings) to BAC.

The difference between $dAC(t)$ and inflated $dEV(t)$, using the short-term threshold parameter $\text{Th}_{\text{ST}}$, indicates the Short-Term Concern for Cost overruns indicator, $CC_{\text{ST}}(t)$. A corresponding Response to Short-Term Cost overruns, $RC_{\text{ST}}(t)$, is developed whenever the remaining Contingency reserve, $C(t)$, is available.

The ratio of $EV(t)$ to $AC(t)$ provides the EVM Cost Performance Index, $CPI(t)$, which is used to evaluate the project Estimate at Completion, $EAC(t)$. The difference between $EAC(t)$, BAC, and $C(t)$, is inflated by the Long-Term Threshold parameter $\text{Th}_{\text{LT}}$, which provides the Long-Term Concern for Cost overruns indicator, $CC_{\text{LT}}(t)$. A Response to Long-Term Cost overruns, $R_{\text{LT}}(t)$, is developed whenever the $C(t)$ is available. It involves using part of $C(t)$ to limit the increase in $AC(t)$ and $EAC(t)$. The global Concern for Cost overruns indicator, $CC(t)$, is a function of both $CC_{\text{ST}}$ and $CC_{\text{LT}}$.

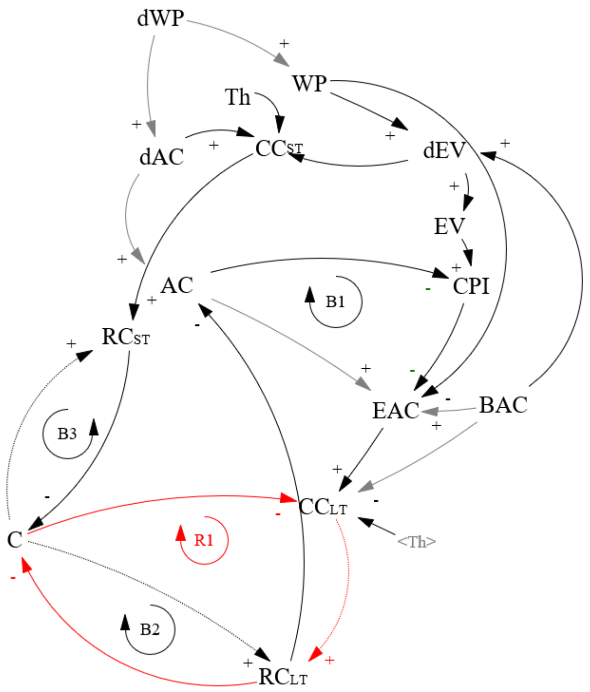


Figure 2. Causal Loop Diagram

In Figure 2, the presented Causal Loop Diagram illustrates the causal interactions among Earned Value Metrics (i.e., Cost Performance Index, Estimate at Completion, and Actual Cost), Contingency Reserve available, project manager's Concern for Cost overruns (i.e., in the Short- and Long-Term), and the consequent project manger's Response to Cost overruns. The diagram comprises three balancing loops (black loops in Figure 2) and one reinforcing loop (red loops in Figure 2) that elucidate the causal structures driving the system's characteristic performance and dynamics. Moreover, all the loops except one are focused on the Long-Term effects of multiple elements on the Response to Cost overrun ($RC_{\text{LT}}$). Conversely, one single balancing loop is focused on the Short-Term effect of Response to Cost overruns ($RC_{\text{ST}}$) on the Contingency Reserve ($C$).

R1 and B2 highlight the simultaneous negative and positive effects of the remaining Contingency reserve on the project manager's Response to Cost overruns. B2 emphasizes the detrimental consequences of having a significant remaining Contingency reserve ($C$) that may trigger an increase in the Long-Term Response to Cost overruns ($RC_{\text{LT}}$), resulting in an accelerated depletion of the remaining Contingency reserve ($C$).

Conversely, R1 focuses on the coexistence of a positive impact of having a significant remaining Contingency reserve ($C$), which may lead to reducing the Long-Term project manager's Concern for Cost overrun ($CC_{\text{LT}}$), resulting in lowering the Long-Term Response to Cost overruns ($RC_{\text{LT}}$) and avoiding excessive spending of the remaining Contingency reserve ($C$).

B1 exposes the balancing effect of the Cost Performance Index ($CPI$) on the Long-Term Response to Cost overruns ($RC_{\text{LT}}$). A low Cost Performance Index ($CPI$) raises the Estimate at Completion ($EAC$), prompting higher Long-Term Concern for Cost overrun ($RC_{\text{LT}}$) that triggers the Long-Term project manager's Response to Cost overruns ($RC_{\text{LT}}$), thus limiting the Actual Cost ($AC$) and, consequently, enhancing the Cost Performance Index ($CPI$).

Lastly, B2 emphasizes the detrimental consequences of having a significant remaining Contingency reserve ($C$) that may trigger an increase in the Short-Term Response to Cost overruns ($RC_{\text{ST}}$), resulting in an accelerated depletion of the remaining Contingency reserve ($C$)

### B. *Contributions and implications*

The System Dynamics model proposed constitutes a valuable tool to assist project managers' decision-making in defining risk contingency spending, considering the relationship between risk response strategy, cost performance, and project managers' concerns derived from this performance. The model aims to capture and analyze the feedback loops that drive the behavior of risk contingency spending. An essential feature of the proposed model is its capability to incorporate feedback loops, thereby providing a comprehensive understanding of the intricate interactions between different factors that shape project managers' risk perception and response.

The System Dynamics model presented in this study constitutes a valuable tool for project managers. Through the identification of feedback loops associated with specific risks, future research can develop quantitative models and frameworks to assess the potential impacts of different risk management strategies on contingency reserves. Additionally, the model contributes to the academic discourse on Project Risk Management by emphasizing the significance of a systemic approach to understanding and managing contingency reserve spending.

Findings highlight the need for a nuanced approach to managing the Contingency Reserve. Simply having a large reserve does not guarantee better outcomes; it requires careful balancing and monitoring to optimize its effectiveness.

Project managers should consider the Long-Term effect of the Contingency Reserve and increase their awareness of the potential trade-offs involved in its utilization. The reserve should be managed strategically to minimize excessive spending while addressing project manager's concern for cost overruns, especially for risk averse project managers.

The Cost Performance Index ($CPI$) serves as an important indicator in influencing the Long-Term Response to Cost overruns. Project managers should pay attention to the CPI and take appropriate actions to control costs and improve performance.

Short-term decisions regarding the Response to Cost overruns should be made cautiously, considering the potential negative consequences of a significant remaining Contingency Reserve. Careful monitoring and management of the reserve are necessary to avoid unnecessary depletion and maintain project stability.

In this study, we have presented a qualitative representation of the causal relationships among key variables using a Causal Loop Diagram. The diagram has provided insights into the complex interconnections and feedback loops that drive the system's performance and dynamics. Building upon this qualitative foundation, there is a clear need for further research to develop a quantitative model that enables the assessment of different strategies and the optimization of project contingency management. By assigning numerical values and equations to the variables and their interactions, a simulation model that replicates the behavior of the system can be developed. This quantitative model can then be used to test various strategies and scenarios, allowing project managers to make informed decisions regarding contingency management.

Furthermore, the development of a quantitative model would facilitate the implementation of optimization techniques. By incorporating optimization algorithms, it can be identified the optimal allocation and utilization of the Contingency Reserve based on specific project objectives and constraints. This optimization framework can help project managers proactively manage cost overruns and make effective use of available resources.

Moreover, conducting empirical studies and case analyses that involve real-world projects would provide valuable insights into the practical implications and limitations of the proposed framework. By comparing the outcomes predicted by the quantitative model with actual project outcomes, we can evaluate the accuracy and reliability of the framework in supporting decision-making and improving project performance.

## V. CONCLUSIONS

This study presented a qualitative representation of the interconnections and feedback loops within a project management system using a Causal Loop Diagram. The diagram has shed light on the causal relationships and dynamics that govern cost overruns, contingency reserve utilization, project managers' concerns, and responses to cost overruns. The findings emphasize the need for a holistic and strategic approach to managing the Contingency Reserve and highlight the significance of considering both short-term and long-term effects.

The proposed model provides a valuable tool for project managers to enhance decision-making in risk contingency spending. By incorporating feedback loops, the model captures the intricate interactions between risk response strategies, cost performance, and project managers' concerns, thereby offering a comprehensive understanding of the dynamics involved. This systemic approach emphasizes the importance of considering the interdependencies between different factors in project risk management.

Future research directions include the development of a quantitative model based on the qualitative Causal Loop Diagram. Such a model would enable the assessment of different strategies and the optimization of project contingency management. By assigning numerical values and equations to the variables and their interactions, a simulation model can be created to replicate the behavior of the system. This quantitative model, coupled with optimization techniques, can assist project managers in making informed decisions regarding the allocation and utilization of the Contingency Reserve.

Furthermore, empirical studies and case analyses involving real-world projects would provide valuable insights into the practical implications and limitations of the proposed framework. Validating the model and framework using actual project data would contribute to its accuracy and reliability in supporting decision-making and improving project performance.

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