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THE LAST CONTROLLER: A HUMAN-CENTRIC APPROACH TO VALUE DELIVERY IN CONSTRUCTION PROJECT CONTROLS

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ABSTRACT

This paper evaluates traditional construction Project Control Systems (PCS), identifying limitations in effectively managing project variability, complexity, and real-time decision-making. Conventional PCS models, largely reliant on single-loop feedback mechanisms, often prove inadequate for the dynamic and rapidly evolving nature of contemporary projects. Addressing this gap, the research synthesizes interdisciplinary literature from mechanical and electrical engineering, business management, and lean construction to propose an advanced framework termed Future Project Controls (fPC). Central to this framework is the introduction of the "Last Controller" role, a human-centric concept emphasizing rigorous final-stage quality assurance, value delivery, and proactive variability management, complementing the Last Planner System. The fPC framework integrates feedforward, concurrent, and feedback control mechanisms tailored to each project stage, enhancing responsiveness, resilience, and value delivery. The paper highlights the importance of clearly defined stage-specific metrics, systematic disturbance management, and adaptive learning across multiple projects. Finally, it outlines key areas for future research, including validating controller-specific performance indicators, leveraging artificial intelligence to enhance predictive controls, evaluating scalability across diverse projects, examining organizational and behavioral influences, and assessing long-term benefits. This comprehensive approach seeks to significantly improve project outcomes through more effective, integrated, and human-focused project controls.

KEYWORDS

Lean Project Controls, Lean Construction, Feedforward, Last Controller, or Concurrent Control

INTRODUCTION

Control systems are fundamentally comprised of three key components: inputs, the process under control, outputs, sensors monitoring performance and health, controllers, actuators executing control actions and disturbances causing variability (Teixeira, 2015). Research consistently identifies these core components as essential to achieving effective control across multiple industries. Traditionally, project controls have focused on accurate measurement and consistent tracking of deviations from baselines, but less on developing effective control strategies, understanding their effect and using advanced methods to improve decision-making (Pellerin, R., 2019). The deeply perceptive adage "You get what you measure" points out the

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important need to adjust measurements with objectives and this alignment is necessary for achieving meaningful results. Research shows that measures drive management behavior and influence organizational performance (de Waal, 2002). Project control practices frequently fail to achieve alignment because of inadequate understanding and implementation (Shabbir, 2023).

Construction projects encounter several difficulties, and these are largely due to their control systems (Rowings, 1991). Heavy reliance on human input introduces meaningful variability, which often leads to biases that diminish predictability (Sutherland, 2015). Existing methods depend considerably on interval-based measurements, typically monthly. This approach fails to catch the fast-developing nature of construction projects. These practices greatly delay feedback and inhibit feedforward. This forces project teams to react in lieu of proactively dealing with problems. Ignoring discussions about control actions and their effect obstructs effective current project controls (cPC). Several conventional models, including the importantly meaningful single-loop feedback control model described by Barrie and Paulson (1992), concentrate on identifying all deviations and subsequently correcting each of these errors. This model carefully employs the planned schedule as an analytically important baseline; important adjustments are precisely guided by consistently conducted progress checks. Real-time project management frequently finds this model inadequate due to slow feedback and decision-making processes, further complicated by several external aspects such as procurement issues or ecological conditions. Koskela and Howell (2002) addressed these weaknesses by offering a better model that included active learning and strong feedback mechanisms. This promising approach doesn't fully account for the complexities of construction, especially the detailed, layered and transfer of value control systems.

This paper examines several control system methodologies drawn from mechanical and electrical systems and business management, to improve construction PCS. A more thorough framework results from combining feedforward and concurrent controls with standard feedback mechanisms. Acknowledging the meaningful role of workers as active, autonomous controllers within the system, rather than passive executors, introduces an analytically important human-centric dimension to construction projects and this considerably changes our comprehension of these projects. This paper expands the comprehension of project controls through the integration of a large body of knowledge from monitoring and evaluation systems, along with business systems. This paper pinpoints key missing elements, such as effective actionable control strategies and strong decision-making frameworks and create a solid foundation for future research. The proposed future Project Controls "fPC" framework tackles project challenges to improve results, minimize inconsistencies and further detail quality management to the evolving demands of the current construction industry.

LITERATURE REVIEW

Project control systems (PCS) are important for successfully finishing construction projects on time and to specifications (Rozenes, 2006). A PCS refers to an integrated set of methods, tools, and processes that systematically monitor and manage project performance relative to planned objectives, such as cost, time, quality, and scope (Rozenes, 2006; Yean, 2013). PCS thus facilitates decision-making and proactive management of project variances, ensuring timely corrective actions to maintain alignment with overall project goals. Conventional PCS models focus mainly on feedback mechanisms (Yean, 2013). These models often prove insufficient for the many and fast-developing complexities of modern construction projects (Williams, 2013). This literature review examines three key theoretical frameworks, five methodological improvements and many critiques of PCS, concentrating on lean construction principles, complexity theory and revolutionary control mechanisms.

Project management has fundamentally relied on the single-loop feedback control model. Barrie and Paulson (1992) explain that this model uses predetermined standards, including schedules, to regularly check progress. These assessments show differences that determine what actions need to be taken. Koskela and Howell (2002) argue that delayed feedback considerably limits the usefulness of this model in many applications, making it unsuitable for many real-time situations. The model they propose leverages continuous learning and strong feedback loops to improve PCS adaptability. Although project control theory has improved, common PCS frameworks often overlook the hierarchical and parallel controls and detailed relationships within project production systems (Meadows, 2008). This gap matters due to the many stakeholders, processes and external factors involved in construction projects, all of which introduce variability and risk to the ultimate delivery of value to the value generator.

LAST PLANNER SYSTEM FOR ASSISTANCE WITH PRODUCTION CONTROL

Ballard and Howell introduced the Last Planner System (LPS) in 1998. This system elevated the standard on how construction projects are planned and managed. LPS stresses a deeply collaborative and remarkably decentralized approach, as well as Last Planners, those people responsible for executing the work, actively participating in developing and committing to exceptionally detailed, short-term plans (Ballard, 2020). This system improves customary top-down control by encouraging reliable workflows. It also proactively removes obstacles to production. LPS relies on pull planning and collaborative scheduling. This approach promotes reliable commitments and consistent production (Ballard & Howell, 1998). LPS improves project predictability and reduces waste through transparent and accountable operations, guaranteeing projects meet their goals and are executed effectively (Fauchier, 2013). The Last Planner's major role in value stream development and preservation considerably supports the Last Controller concept, which comprehensively extends these principles to production's concluding stages.

Fundamental lean construction principles offer three analytically important perspectives on PCS and these principles are necessary for a thorough analysis. Lean construction necessitates the total elimination of waste. An important aspect is the meaningful value enhancement and the large improvement of flow efficiency across the value stream (Ballard et al., 2002). Lean construction's LPS changes the emphasis from reviewing past problems to detailed, proactive planning and better teamwork in decision-making (Agrawal, 2024). These adjust LPS closely with the feedforward and concurrent control mechanisms discussed by Nise (2020). Lean construction integrates leading and lagging indicators into PCS. Earned value metrics show past performance and are a lagging indicator (Moon et al., 2023), unlike leading indicators such as make-ready metrics, which predict future performance and enable immediate adjustments. This approach meets the larger need for flexible, multi-layered controls in complex projects.

Construction's comprehension of PCS benefits from complexity theory. These principles considerably aid its deep comprehension. Meadows (2008) stresses that many systems, such as PPS, are complex social systems with a collection of dynamic interactions, several feedback loops and a variety of emergent behaviors. Successful PCS solutions require tools that address variability and promote resilience to handle complex situations (Carmichael, 2015). Strong design practices limit variability in modern manufacturing systems. This is achieved through buffer mechanisms and flexible processes, as described in the work of Shetty & Kolk (2010). Recent research points out the importance of digital technology in PCS, thus stressing the need for improved complexity management (Kermanshachi, 2016).

Growing evidence supports the need for hybrid control systems in construction using feedforward, feedback and concurrent control mechanisms (Kuo, 2002). Unlike concurrent controls, which react to current problems, feedforward controls use leading indicators to predict and address issues (Nise, 2020). These mechanisms adjust with core lean principles. They stress efficient workflow, meaningful value creation and waste elimination (Hamzeh, 2008). Customary PCS models offer a basic structure; however, the natural complexity of many modern construction projects demands a shift towards dynamic, integrated, as well as adaptive control systems (Ireland, 2020). The Last Controller differs from the Last Planner in its explicit focus on ensuring final quality assurance, effectively managing variability, and resolving disturbances prior to final turnover, rather than focusing solely on task readiness.

METHODOLOGY

This study employed a systematic literature review and conceptual synthesis approach to develop the Future Project Controls (fPC) framework. Initially, existing project control methodologies, including feedback, feedforward, and concurrent mechanisms, were critically evaluated using lean construction principles, complexity theory, and contemporary management practices to identify gaps and opportunities (Ballard, 2012). Literature was sourced systematically from databases including ScienceDirect, Google Scholar, ASCE Library, Clemson Library, and the IGLC conference database, using terms such as "Project Control Systems," "Last Planner System," and "Lean Construction," supplemented with insights from mechanical, electrical, and business management literature to introduce cross-disciplinary perspectives (Senivongse, 2017). The collected literature was analyzed to assess current PCS effectiveness in real-time adaptability, variability management, and human-centric decision-making, while identifying key limitations in traditional, schedule-centric feedback models. These insights informed the conceptual development of the fPC framework, introducing the "Last Controller" to enhance human-centric quality control, proactive planning, and value delivery, clearly defining controller roles across the value stream. Initial validation involved qualitative expert consultations with construction industry practitioners and lean construction specialists, ensuring the framework's practical applicability.

EVALUATION AND SYNTHESIS OF PCS LITERATURE

This section synthesizes literature on control systems from mechanical and electrical engineering (M&E), business management, and lean construction, identifying conceptual commonalities and methodological gaps essential for advancing human-centric project control in construction. Control systems exist across various industries, each uniquely tailored to operational challenges and objectives. This synthesis systematically evaluates core system components such as: inputs, outputs, sensors, controllers, actuators, and disturbances, and categorizes control mechanisms into open-loop, closed-loop, and concurrent types. Insights gained from this analysis provide a foundation for enhancing complexity management, responsiveness, and value creation in construction Project Production Systems (PPS).

COMPLEXITIES WITHIN CONTROL SYSTEMS

Analyzing control systems involves understanding their purpose, components, processes, design, limitations, behaviors, and dynamics, particularly within Project Production Systems (PPS), which ensure efficient performance and intended outcomes (Yean, 2013; Africa, 2019). Definitions of control relevant to PPS include determining or supervising behavior; knowing the state of the system; and influencing behaviors or events (Oxford Dictionary, 2020). In PPS, control encompasses the capability to directly or indirectly influence events, requiring deliberate decision-making within complex social systems (Meadows, 2008). Thus, control includes choosing appropriate actions to enhance stakeholder value through project delivery, operation, maintenance, and repurposing of high-performing facilities (Fischer, 2013). Control actions in other domains (e.g., finance, IT) similarly focus on risk minimization (Shenkir, 2006). Further, business management views control as the efficient and effective utilization of organizational resources toward defined objectives (Cambalikova, 2017). Given that PPS are temporary organizations designed around specific operational activities (Oerlemans, 2014), control must not only optimize stakeholder value but also promote operational efficiency and effectiveness.

DEFINITION OF CONTROL

Control, by definition, means influencing, guiding, or directing a system to achieve its intended purpose. PPS has both direct and indirect effects on system outcomes. Control involves defining, monitoring and influencing systems or processes. This includes determining or supervising its behavior and understanding its current state precisely. Exercising authority to take actions affecting its behavior is also included. PPS control is rapidly developing. This is because it manages a complex social system. The system's goal is to build and maintain stakeholder value throughout the project lifecycle and this includes everything from delivery and operation to maintenance and repurposing of high-performing, long-lasting facilities, instead of concentrating only on task execution. PPS control must effectively guide all processes, guaranteeing decisions about necessary actions are fully informed and maximize value.

Traditional project controls typically stress schedules; however, this emphasis on deadlines may cause other important elements, like quality management and the human effect on quality, to be overlooked (Lipke, 2013). Quality guarantees that all component specifications are met and that project goals are consistently changed throughout every phase, from initial concept to final handover (Ashford, 2002). Ignoring quality at any point builds up risks that can harm the project's success (Ogwueleka, 2013). This challenge highlights the necessity for integrated control systems that effectively align quality management, scheduling, and risk mitigation across the entire project lifecycle, from procurement through final completion. To achieve these goals, professionals at all levels, from designers to tradespeople, must be equipped with appropriate tools and metrics to enhance value generation, efficiently allocate resources, manage disruptions, and ensure stability, thus addressing the dynamic interplay among the system's multiple components to maximize stakeholder value.

DEFINITION OF THE LAST CONTROLLER

The "Last Controller," analogous yet distinct from the Last Planner concept introduced by Ballard and Howell, refers specifically to the final responsible individual who ensures all completed project deliverables precisely satisfy the client's defined expectations and quality specifications prior to final project turnover. Whereas the Last Planner is primarily concerned with task scheduling, planning reliability, and the execution of commitments (Olano, 2009), the Last Controller emphasizes verification of task completion, rigorous quality assurance, management of residual variability, and the safeguarding of delivered value. By clearly delineating accountability, this role significantly reduces rework, post-handover discrepancies, and ensures superior final product quality.

Acting as the principal quality gatekeeper, the Last Controller systematically validates compliance with design specifications, safety standards, and client requirements. This role not only finalizes the value stream but also addresses and resolves any outstanding variances, ultimately protecting the project's integrity and ensuring the excellence of the delivered product. By formally defining the Last Controller, this paper contributes a critical human-centric dimension to project controls, underscoring the necessity for specialized expertise, disciplined practice, and focused dedication. Recognition of the Last Controller's pivotal position within the project value stream highlights the importance of developing targeted performance metrics and supportive management frameworks to reinforce accountability and enhance project outcomes.

Core Components and Application of Control Systems in project production

Control systems universally consist of fundamental components: inputs, outputs, the controlled process, sensors, controllers, actuators, and disturbances (Nise, 2020). Inputs represent targeted performance outcomes aligned with specific project goals or operational objectives (Baccarini, 1999). The controlled process systematically transforms inputs into measurable and anticipated outputs, represented by tangible deliverables and defined key performance indicators (KPIs) (Skogestad, 2023). Sensors continuously gather real-time data on the system's current state and environmental factors, relaying this information to controllers for analysis. Controllers evaluate this data against predefined objectives and direct actuators to adjust inputs, accordingly, ensuring outputs meet intended criteria. Advanced mechanical and electrical (M&E) systems exemplify this integration, utilizing precision sensors and predictive algorithms within building automation to optimize performance, energy efficiency, and user comfort (Stengel, 1991).

In Project Production Systems (PPS), adapting these core components addresses construction's inherent complexities. Inputs include stakeholder-defined Conditions of Satisfaction (COS) and explicit project goals, with outputs represented by actualized project value at completion. PPS-specific sensors, such as progress monitoring tools, quality inspections, and productivity metrics, provide critical data enabling prompt detection of deviations. Controllers (e.g., project managers and superintendents) interpret sensor data to make informed corrective decisions, including resource reallocation and schedule adjustments, thereby ensuring alignment with project objectives and timely milestone achievement.

Categories Of Control: Open Loop, Closed Loop, And Concurrent

Control systems can be classified into open-loop, closed-loop, and concurrent types, each with distinct applications (Levine, 2019). Open-loop systems operate without feedback, relying entirely on predefined inputs; feedforward control is an advanced form of open-loop control utilizing predictive models to proactively mitigate anticipated disruptions, exemplified by pre-employment screening in business (Lin, 2010). Closed-loop systems incorporate feedback for real-time adjustments, comparing actual outputs against targets to correct deviations, though inherent delays may limit their effectiveness, as seen in retail inventory management following sales promotions (Sahoo, 2002). Concurrent control systems integrate feedforward and feedback approaches, enabling proactive identification and immediate correction of issues through continuous monitoring and real-time intervention (Singh, 2015). Examples include GPS-based construction vehicle tracking systems that optimize operational efficiency. Effective Project Production Systems (PPS) management requires the cohesive integration of these control types, combining predictive assessments aligned with lean construction indicators, real-time adjustments, and feedback-informed strategic refinements to enhance overall project performance and risk management.

Relevance To PPS And Lean Construction

The Last Controller concept enhances the application of PPS and aligns closely with fundamental lean construction principles by emphasizing proactive quality management, flow efficiency, and systematic variability reduction. Within PPS frameworks, the Last Controller serves as a critical gatekeeper, responsible for verifying that the delivered work consistently adheres to defined client expectations, specifications, and established quality benchmarks. This rigorous final-stage quality assurance mitigates residual variability and minimizes rework, thus ensuring greater reliability and value at project turnover.

From a lean construction perspective, the Last Controller complements and extends the Last Planner System's emphasis on collaborative planning, individual accountability, and proactive management of workflow disruptions. By integrating advanced feedforward, feedback, and concurrent control mechanisms, borrowed from mechanical and electrical engineering as well as business management, PPS can systematically address complexities inherent in construction projects. The Last Controller operationalizes these advanced control strategies, reinforcing real-time adaptability and proactive intervention at critical junctures, ultimately contributing to continuous improvement, optimized resource utilization, and robust delivery of stakeholder value across the project lifecycle.

MODEL OF FUTURE PROJECT CONTROLS (FPC)

To manage a project production system, you need to know its capabilities and how everything fits together. Temporary PPS organizations need to decide whether their projects work independently or as part of a continuous improvement system that shares lessons learned across all projects (Oerlemans, 2014). That viewpoint supports continuous improvement; repeated feedback and adjustments improve project outcomes.

Adopting a considerably larger perspective on PPS boundaries points out the importance of several key system design practices, such as those employed in manufacturing to reduce variability and guarantee stability (Shetty, 2010). Confining control boundaries to the duration of a single project can considerably stifle adaptability, for the process of redesigning and refining the PPS throughout its entire lifecycle is important for minimizing several disruptions and maintaining consistent alignment with project goals (Abramovici, 2010).

HIERARCHICAL CONTROL AND THE VALUE STREAM

Figure 1 illustrates various stages that construction process value must undergo before actual value creation takes place in the field. Value originates from the initial entity responsible for defining the purpose or need and continues through multiple intermediate stages until it reaches the last controller. Each stage contributes progressively to the overall value delivered to the final output. Information flows continuously between stages through feedforward and feedback loops, enabling constant adjustments and enhancing the effectiveness of the value stream.

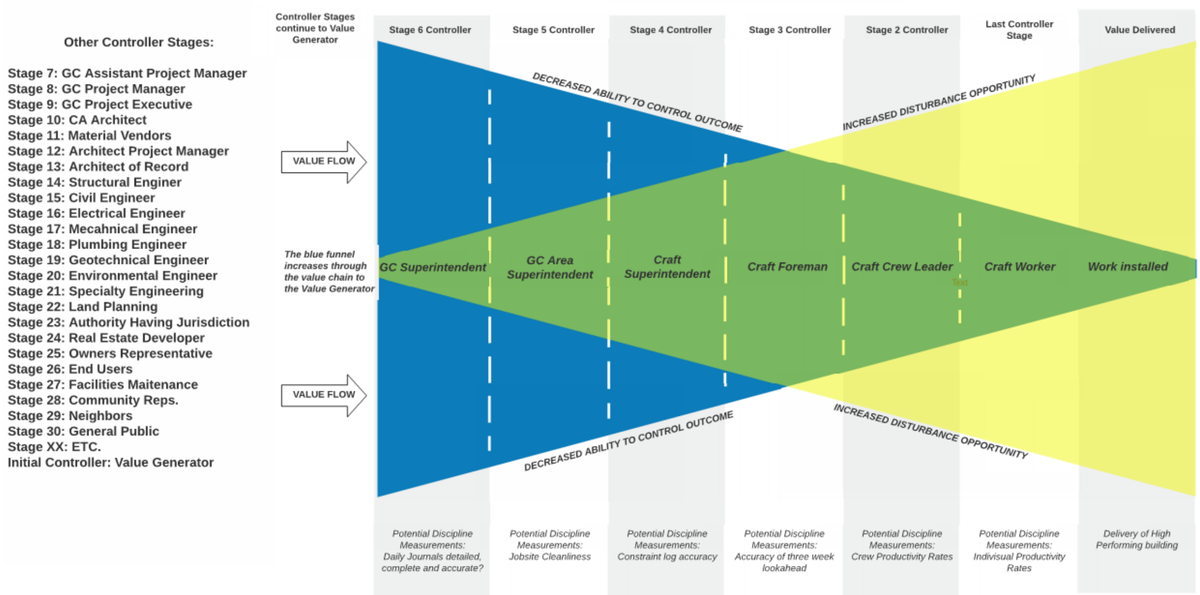

Figure 1: Controller Stages of Value Complexity

This value will pass from each value controller who is generating reason for value all the way to the last controller of value. Each stage contributes value add towards the value requestor's final deliverable. However, it's important to note that at each stage of value creation, there are four levels of potential disturbance as is noted in the below figure 2. These 4 levels of disturbance are noticed when 1) information is transferred between controllers 2) Before a process is established to move value forward 3) during the process and 4) after the process is complete. The hope is that these disturbances lead to creative and lean solutions to better project outcomes. This information will make it back to the process via feedforward and feedback loops. When you multiply the 4 levels of disturbance times each stage of value controller, one can begin to see the complexities with project controls in the construction industry.

Let's review each of these potential disturbance points from a real-life construction example. Consider a scenario where a value generator requests that a hole be excavated. Initially, a communication error arises (D1): the architectural and civil drawings provide conflicting information regarding the precise location for digging. Before excavation begins (D2), additional complications arise—someone has placed extra dirt atop the intended dig location, and the ground is discovered to be frozen solid. During excavation (D3), after clearing excess dirt and thawing the ground, the crew encounters unexpected rock, requiring additional equipment and time beyond the original estimates. Lastly, after excavation is complete (D4), heavy rain and interference by another trade partner, who inadvertently drives a lift too close, cause one side of the excavation to collapse, leading to further corrective efforts before project completion can be finalized.

It is important to recognize that each identified disturbance point serves merely as a pathway through which variability can enter the project system. Not every controller will experience disturbances equally; some may encounter fewer, while others might face multiple variations across these channels as value progresses through the project. The primary goal of this research is to develop methods to effectively measure and mitigate waste at every stage of the value stream, thereby enhancing the project's overall performance.

PPS control systems work on multiple levels, each offering advantages but also possibly leading to problems. The Control Complexity Circuit Diagram in figure 2 depicts a value stream originating from the Value Generator, progressing through multiple stages to its conclusion with the final controller, the individual responsible for both installation and value turnover delivery.

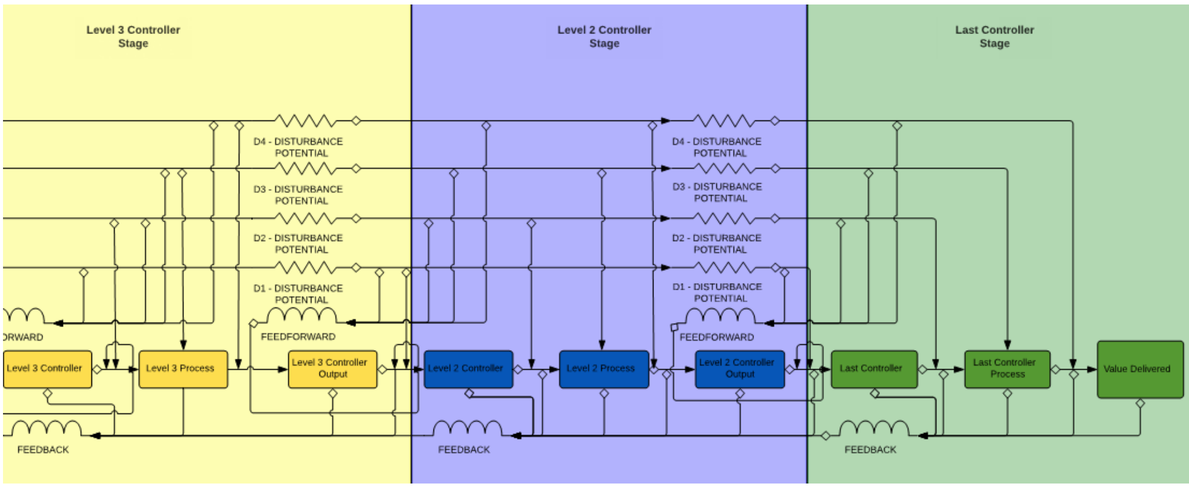

Figure 2: Control complexity at each stage

MEASURING SUCCESS AT EACH STAGE

The authors recommend developing customized performance metrics for each stage of the value stream to accurately reflect the unique responsibilities and contributions of each controller. For example, General Contractor (GC) Superintendents at Stage 6 could be evaluated based on the accuracy and thoroughness of their daily journals, providing insights into their planning and oversight effectiveness. Similarly, Area Superintendents at Stage 5 might be assessed on site cleanliness and the accuracy of their constraint logs, while Craft Foremen at Stage 3 could have their performance measured by the reliability of their approximately three-week lookahead schedules. At Stage 1, the Last Controller's effectiveness could be gauged using productivity rates and other specific performance metrics directly linked to value delivery. Customizing these metrics ensures that each controller clearly understands their role in achieving overall project goals. However, this paper does not cover metrics for all stages of the value stream.

INTEGRATING FEEDFORWARD AND FEEDBACK MECHANISMS

Effective control in PPS requires integrating proactive and reactive adjustments to effectively manage issues and optimize performance. Feedforward mechanisms proactively identify risks, enabling controllers to mitigate potential disruptions before they occur, while feedback mechanisms facilitate learning from past outcomes, ensuring corrective actions are informed by actual results. Concurrent controls provide real-time oversight, crucial for addressing immediate challenges within dynamic environments such as construction sites. By recognizing the interconnectedness of controllers within the PPS and customizing control mechanisms for each stage, construction projects can achieve enhanced alignment, resilience, and efficiency. Through precise measurement of success at each stage and proactive management of potential disruptions, the value stream is maintained, enabling consistent delivery of value-add activities.

CONCLUSION

Project controls are important for successful construction, giving projects a framework to handle complexity, reduce risks and meet everyone's expectations. Construction project controls have meaningful drawbacks. Overreliance on customary schedule-focused metrics and excessively long feedback cycles are two meaningful factors and insufficient mechanisms for dealing with quality and variability in dynamic project environments constitute a third. These shortcomings often lead to about half of all decisions being reactive, resulting in many missed opportunities to optimize processes, along with obscuring paths to high-performing buildings. This paper thoroughly analyzes these vulnerabilities and recommends a meaningful change to how project controls are understood and used.

This paper presents a thorough framework for future Project Controls (fPC) to considerably improve current cost performance control (cPC). The fPC framework represents an important improvement over static, rigidly schedule-centric methods, transitioning to highly dynamic, comprehensively integrated systems that stress substantially proactive planning, instantaneous real-time adaptability and human-centric decision-making. Project teams can better anticipate and manage variability throughout the value stream because of key improvements including highly effective feedforward and concurrent controls and strong feedback mechanisms. This framework helps the Last Controller and others, actively participate in quality assurance and value delivery. The fPC framework points out the human element in construction. The Last Controller plays a major role in final quality control, adjusting with lean construction principles.

This paper provides a thorough guide to assist the construction industry in dealing with several important, persistent inefficiencies natural in many current project control methods. The fPC framework improves project success by assisting leaders in swiftly identifying and resolving bottlenecks. This is achieved through practical guidance, open communication and perceptive performance metrics. Completely open communication is analytically important for effectively identifying and resolving hidden obstacles and these obstacles are frequently the most important threats to project success.

This paper advances the theoretical foundations of research project controls. It integrates understandings from mechanical and electrical systems, complexity theory and lean construction. It comprehensively integrates many academic disciplines, providing a highly unified, flexible framework that continuously evolves with the demands of contemporary construction. Introducing the Last Controller concept improves our comprehension of the meaningful role of individual accountability in delivering value and it also illuminates the large contribution of quality control to this process. This paper deeply and comprehensively reshapes the comprehension of project controls and their application in construction. It boldly challenges the existing power structures, advocates for a thoroughly complete as well as highly flexible approach, in addition to decisively setting the stage for the next generation of many PCS.

RESEARCH LIMITATIONS

This study establishes a theoretical foundation for a Future Project Controls (fPC) framework while acknowledging limitations. First, it relies primarily on conceptual synthesis of interdisciplinary literature without extensive empirical validation through case studies, highlighting the need for further field testing. Second, practical aspects of implementing the human-centric "Last Controller" concept, including organizational resistance and training needs, were not thoroughly examined. Third, the study's scope restricted detailed development of stage-specific performance metrics, necessitating additional research. Lastly, while integrating advanced predictive technologies like artificial intelligence was discussed conceptually, further in-depth evaluation is required to determine real-world feasibility and effectiveness.

FUTURE RESEARCH DIRECTIONS

This paper establishes the foundation for the future Project Controls (fPC) framework; however, further research is needed to strengthen its applicability and effectiveness. Key areas for future exploration include: (1) developing and validating specific performance metrics for each controller stage, emphasizing precise measurement of roles such as the Last Controller; (2) examining how advanced AI and predictive analytics can enhance feedforward and feedback controls for improved decision-making; (3) assessing the adaptability, scalability, and practical implementation barriers of the fPC framework across multiple construction projects; (4) investigating how behavioral and organizational dynamics, including leadership and team processes, influence fPC success; and (5) evaluating the long-term organizational benefits, learning, innovation, and knowledge transfer resulting from adopting fPC methodologies. Advancing the future Project Controls (fPC) framework will enable the construction industry to better manage complexity, optimize performance, and consistently deliver exceptional value.

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