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OPTIMIZED CYCLE-TIME FLOW BATCHING: ENHANCED PERFORMANCE IN PROJECT PORTFOLIO MANAGEMENT

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ABSTRACT

As organizations in the AEC industry increasingly work within multi-project environments, there is an urgent need for lean Project Portfolio Management (PPM) strategies to ensure effective project prioritization, resource management, and alignment with organizational goals. While lean construction approaches have been proven effective at the single-project level, they do not address portfolio issues, such as flow of trades between projects and strategic prioritization across multiple projects. This study introduces and discusses the project grouping considerations of Optimized Cycle-Time Flow (OCF), a pull-based methodology designed to enhance portfolio performance by grouping projects into manageable batches based on trades' demonstrated capabilities and customers priorities. By optimizing the mixture, sequence and timing of batches, this approach leads to improved alignment with organizational priorities. Using a comparative analysis between two semiconductor plant project portfolios, each comprising hundreds of projects, the study demonstrates the effects of OCF Batching: stabilization of WIP levels, reduction of individual projects' cycle times, and enhanced overall portfolio performance. The findings validate OCF as a powerful lean approach for PPM and suggest that it can enhance efficiency for project-based organizations.

KEYWORDS

Batching, Optimized Cycle-Time Flow (OCF), Production Planning and Control, Project Portfolio Management, Strategy

INTRODUCTION

Many major construction clients operate as project-based organizations, driven by the need to manage multiple complex projects simultaneously and efficiently. This setting is prevalent across various sectors in construction, including healthcare organizations (which initiate new hospital construction and large-scale renovations), government infrastructure agencies (responsible for public utilities development and maintenance), major industrial companies, as well as private builders and manufacturers in the housing sector. All these entities require

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Project Portfolio Management (PPM) practices to streamline their processes and enable prioritization to deliver the right projects on time and within budget.

Within the Lean Construction (LC) body of knowledge, there is relatively limited research on or documented applications for PPM. In 2018, Intel introduced Optimized Cycle-Time Flow (OCF) as a lean-based methodology for PPM (Pemberton 2018). OCF has since been implemented in over 2,000 projects across the organization (Gabai et al. 2023, 2024; Gabai and Sacks 2020). OCF was originally developed for construction management of multiple semiconductor plants, each comprising thousands of projects. Critical lean production thinking stands at the core of OCF, striving to improve organizational throughput, by reducing Cycle Time (CT) at the single project level, while levelling the Work in Progress (WIP - the number of projects that are actively being executed within the portfolio at any given time), and thus reducing time to market for new production lines in the Fab.

OCF Batching, a novel project batching (grouping) methodology, is an essential part of OCF strategy. When handling portfolios of hundreds of projects, methodical prioritization and selection of projects to be undertaken is of great importance (Archer and Ghasemzadeh 1999; PMI 2017). This is necessary from initiation and design, triggering the supply chain on time for long lead items (LLI), and allowing construction on site to start only after constraint removal. OCF Batching aims to shift from the traditional “as-soon-as-possible” push approach, which results in inflated WIP and chaotic resource allocation (Hopp and Spearman 1996) towards a pull approach that facilitates a focused managerial effort on projects that have been grouped, preparing them for construction. Thus, the constraint removal process occurs not only at the individual project level but gradually expands to the batch level. In the formation of each batch, attention is given to the combination of different types of projects, to enable flexibility and smoother resource flow between projects.

In this paper we present an initial exploration of OCF Batching methodology and demonstrate the results through a case study from the semiconductor construction sector. We present results from OCF Batching implementation on over 1,000 projects, divided into two portfolios of tool installation projects in the same Fab, through two distinct periods: pre-OCF and OCF. The pre-OCF portfolio was characterized by a push-based scheduling approach, initiating projects as early as possible. This in turn, led to high levels of WIP and long CT. In the OCF portfolio the organization worked according to the OCF Batching methodology, and only ready and required projects were pulled for construction. Accordingly, this period was characterized by a significant reduction in WIP and CT, and eventually enabled a 5-month early completion of the portfolio and, consequently, early activation of the new production line.

LITERATURE REVIEW

PROJECT PORTFOLIO MANAGEMENT

Project Portfolio Management (PPM) is defined as “the centralized management of one or more portfolios, enabling executive management to meet organizational goals through efficient decision-making and resource allocation” (PMI 2017). PPM focuses on selecting, prioritizing, and controlling projects to balance demands and interdependencies, resolve resource constraints, and eventually enhance organizational throughput (TH) (Archer and Ghasemzadeh 1999).

In LC, the application of PPM remains relatively unexplored. Most LC methods and tools, such as the Last Planner System (LPS) (Ballard 2000) or Target Value Design (TVD) (Zimina et al. 2012) focus on the individual project level and do not address the complexities of multi-project management. The Portfolio, Process and Operations (PPO) model (Sacks 2016) enables a holistic understanding of production flow across portfolios of construction projects, based on three flows: flow of projects, flow of locations within a project, and flow of trade crews in and between locations across portfolios of projects. The PPO perspective opens the door for further integration of LC in PPM with emphasis on the flow of trades between projects, and for multi-project organizational planning methodologies. Korb and Sacks (2021) demonstrated this potential by simulating contractor-subcontractor interactions, highlighting the effects of variability in work sequencing and resource allocation across interconnected projects. Their findings underscore the potential and need for a lean-based PPM approach.

BATCHING IN PRODUCTION

Batch size plays a crucial role and can fundamentally determine the performance of production systems. Hopp and Spearman (1996) emphasize that optimal system performance - the "Best Case" scenario - occurs when the WIP level is kept at the critical WIP (W0). This balance allows the system to achieve its maximum throughput (TH), limited by the bottleneck rate, while maintaining minimal cycle time (CT). However, as WIP levels increase beyond the critical threshold, the system approaches the "Worst Case" scenario, as most items are processed in large batches, which increases CT, yet the throughput remains constrained by the bottleneck rate. In the context of building construction, where many consider the entire building to be the sole product, it can be argued that working without any defined and controlled batch size at all implies working with only one batch that includes all items and is equivalent to the "Worst Case" scenario.

In construction projects, batching typically refers to the size and scope of the work packages for each trade, which is influenced by the project's Location Breakdown Structure (LBS) that reflects the level of detail of the planning (Kenley and Seppanen 2010). Thus, it can be argued that within LPS, "work-packaging" serves as a form of batching, structuring manageable units of work that will enable workflow reliability (Ballard 2000). Takt planning further refines the concept of batching in construction as work packages are synchronized into "takts" that enable a steady work rhythm. Takt planning limits the WIP levels and enables coordination of resources according to the predefined pace. Although this may determine operating at a pace lower than the maximum capacity of the system, it gradually leads to higher productivity and reduced cycle times (Frandson et al. 2013; Jang and Kim 2007; Lehtovaara et al. 2021).

In PPM, batching involves organizing multiple projects into structured, manageable groups to enable effective resource allocation and ensure alignment with organizational strategy and capability. A neglected batching process at the portfolio level can significantly impact individual projects and the organization as a whole. Despite the importance of batching in PPM, research and practical implications on this topic remain limited. We argue that the foundational concepts of production management and LC provide valuable frameworks for batching in PPM, and present opportunities for research on LC-based PPM solutions.

Table 1 provides an overview on the concept of batching, from manufacturing to single projects, and eventually to PPM.

Table 1: The Concept of Batching as Expressed in the Literature

	Manufacturing	Single Project	Project Portfolio
Batching Focus	Product Batching	Work packaging	Grouping of projects
Goal	Optimize operations and process flow	Stabilize workflow, reduce variability	Align multiple projects to strategic objectives, capability, and improve organizational throughput
Flow	Sequential operations in a production line	Flow of trades across locations in the project	Flow of trades across multiple projects within the organization

OPTIMIZED CYCLE-TIME FLOW (OCF)

The OCF strategy is built upon Lean Construction (LC) theories, particularly the Portfolio, Process, and Operations (PPO) model (Sacks 2016) and the Transformation-Flow-Value (TFV) theory (Koskela 2000). It focuses on flow and value within Project Portfolio Management (PPM) and multi-project organizations, integrating seven principles derived from proven theories and methodologies that are reinforced and synergized once combined.

The OCF flywheel (Figure 1) begins with Principle I – 'Plan and Integrate Strategically' and Principle II – 'Plan Tactical Targets', both rooted in Strategic Project Leadership® (SPL) (Shenhar 2015). These principles emphasize business-driven strategic planning, incorporating Target Pull Plans to align each project with CT reduction targets and eventually optimize TH at the portfolio level.

Principle III – 'Collaborate' aligns with the LPS (Ballard 2000), emphasizing collaborative planning to improve workflow reliability and production stability.

Principle IV – 'Resolve Constraints', and Principle V – 'Restructure Resources' are based on the Theory of Constraints (TOC) (Goldratt 1997; Goldratt et al. 2004), focusing on identifying and removing bottlenecks (whether physical or informational) that limit the production system (Ballard & Tommelein, 2016).

Principle VI – 'Control Project Start' and Principle VII – 'Ensure Project Flow' are rooted in the Toyota Production System (TPS) (Liker 2001), utilizing a pull-based approach where projects are initiated just-in-time (JIT) based on readiness, demonstrated resource capabilities, and client demand. This structured batching of projects enables controlled WIP levels, facilitating CT reductions at both project and portfolio levels.

Figure 1: The OCF Flywheel (Credit: Intel Corporation).

Previous research has highlighted various aspects of OCF: Gabai and Sacks (2020) introduced the foundational principles of OCF, demonstrating its ability to significantly reduce cycle times. Gabai et al. (2023) extended this by illustrating the scalability of OCF across facilities and project domains, emphasizing its repeatable and consistent implementation. Gabai et al. (2024) demonstrated how doubling of throughput is achieved at the single project level, providing a case study that validates the empirical data.

This paper focuses specifically on OCF Batching as a critical component of OCF. It emphasizes the role of batching in aligning project readiness with strategic priorities, balancing Work in Progress (WIP), and optimizing resource allocation to reduce variability and improve throughput. This paper demonstrates the application of OCF principles at the portfolio level, providing a systematic PPM approach.

OCF BATCHING

OCF Batching is a structured approach to managing project portfolios by organizing them into predictable and manageable groups, or "batches." The optimization of batch size and composition, as presented in Figure 2, ensures teams operate within a stable production system and can maintain a steady workflow. The primary objective with batching is to ensure that when a team starts a project, they can finish it with little to no delays or impacts. Batches are prioritized and executed based on customer demand. Having prioritized batches allows the teams working on the upstream preparation to focus on readiness for a smaller quantity of projects and enable faster constraint closure.

The key principles of OCF Batching are:

1. **Trade Demonstrated Capabilities:** Monitoring the number of available trades and their demonstrated capabilities is the basis to prevent overload and ensure batch sizes remain within reliable capacity. Understanding the capabilities of each Trade partner and utilizing it in the planning process for Batch consideration helps to make sure the results of the work are more reliable. When a company doesn't need to hire a significant amount of people to meet a peak need then let them go once the peak comes down, they can focus their resources and training on the workers who will consistently be around to support them. The target is to provide each trade with a number of projects in each batch that will enable continuous workflow within the capacity constraints.
2. **Customer's Unique Priorities:** Projects are prioritized based on customer-defined goals and milestones, ensuring that critical projects are completed first while maintaining progress across the portfolio. Portfolios may include hundreds or thousands of projects, and clearly there are not enough resources to work on all projects simultaneously. By understanding the customer's priorities, the portfolio management team can make sure the top priorities are done first and forecast how to complete the rest of the work appropriately.
3. **Well-composed Batches:** Each batch includes a mix of projects with varying durations across multiple locations (functional areas in the Fab). Long-cycle projects provide a stable framework for trade deployment, while short-cycle projects fill gaps to maintain continuous trade utilization. This balance ensures that trades can flow seamlessly, while optimizing resource allocation across locations and projects in the portfolio. The overall duration for each batch is driven by the longest projects in the batch. However, it is crucial that each batch includes a mix of long and short projects, enabling a smooth workflow for the trades across projects with different durations. Additionally, projects are distributed across all locations in the Fab to balance the workload, avoiding bottlenecks in specific areas.

Building on these key principles, the **Team Optimization** phase can be applied (see Figure 2), as teams are assigned to specific projects within each batch. This step enables finalization of the Initial Batch Plan 8-12 weeks before construction and initiates **the "make ready" process and constraint removal**. The batch plan undergoes a **Conflicts & Limitations** assessment process, to identify potential conflicts in shared workspaces and interdependencies between projects, ensuring alignment and coordination across the entire portfolio.

As the batch start date approaches, the focus is to confirm that the proper maturity level of each project is obtained. A Go/No-Go decision is made for each project based on its maturity (OCF principle #6); if significant constraints or conflicts remain unresolved, the batch must be adjusted by removing projects that aren't ready and, if possible, pulling others to maintain optimal batch size.

After finalizing the batch size and scope, the **Team Utilization** phase commences, which involves a final readiness check to confirms that design, material, tools, and other resources are fully prepared and available, facilitating a smooth workflow at the team level.

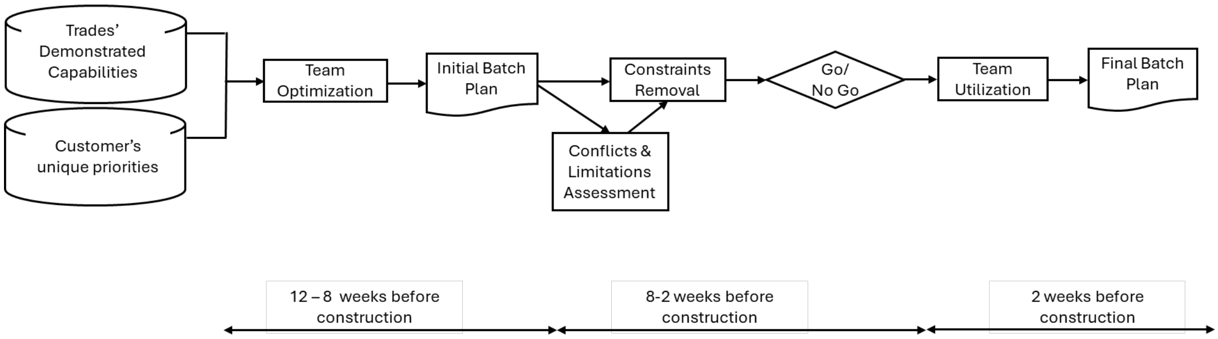

Figure 2: The OCF Batching Process

RESEARCH METHOD

This study employs a comparative analysis within a case study to evaluate the impact of OCF Batching on project portfolio performance, as this method "provides a structured framework for examining changes across uniform metrics, reducing the influence of external variability" (Yin 2009).

The case study includes comparison between two portfolios of tool installation projects in a semiconductor Fab. The first portfolio was undertaken with traditional push-based methods (Pre-OCF), and the second portfolio was undertaken according to OCF strategy. Without OCF implementation, the portfolios maintain relatively high consistency – they are comprised from the same project types and scope; with similar internal-organizational resource investments; and a similar external environment (in terms of trades' availability and market status). Thus, changes in performance observed by the comparative analysis, demonstrated by basic production metrics - CT, WIP, and TH - can be directly linked to OCF batching. Data was collected from Primavera P6 construction plans, and included:

- **The first portfolio (Pre-OCF):** 380 projects, with a total portfolio duration of 26.4 months.
- **The second portfolio (OCF):** 380 projects, with a shortened portfolio duration of 20.6 months, organized into 16 project batches.

The CT for each project was directly extracted from Primavera P6 schedules, measured from the actual start date to the actual finish date. WIP was measured as the number of projects concurrently in execution at any given time and was analyzed over time for each portfolio.

CASE STUDY: SEMICONDUCTOR FAB TOOL INSTALLATION PORTFOLIOS

The case study examines the implementation of OCF Batching across two portfolios of tool installation (TI) projects in one of Intel's fabs. TI projects involve installation of semiconductor manufacturing tools, requiring meticulous integration of multiple specialized trades, including extensive MEP work and specialized piping installations. Both project portfolios analyzed in this research were relatively similar in scope and objectives, and were both necessary to expand production capacity of a fab by installing and upgrading essential tools and equipment.

In the semiconductor construction environment, tool installation projects require millimeter-level precision across multiple levels (including utility level, subfab, and cleanroom, as illustrated in Figure 3). This setting demands extensive coordination among various trades, who often work in close proximity on separate projects. The application of OCF Batching in this environment - a pull-based system that relies on demonstrated trades' capabilities and aligns with client requirements - resulted in a more stable workflow, reduced CT, leveled WIP, and, ultimately, shorter portfolio durations. This approach enabled the fab to meet its production capacity milestones sooner than it may have under standard modes of construction management.

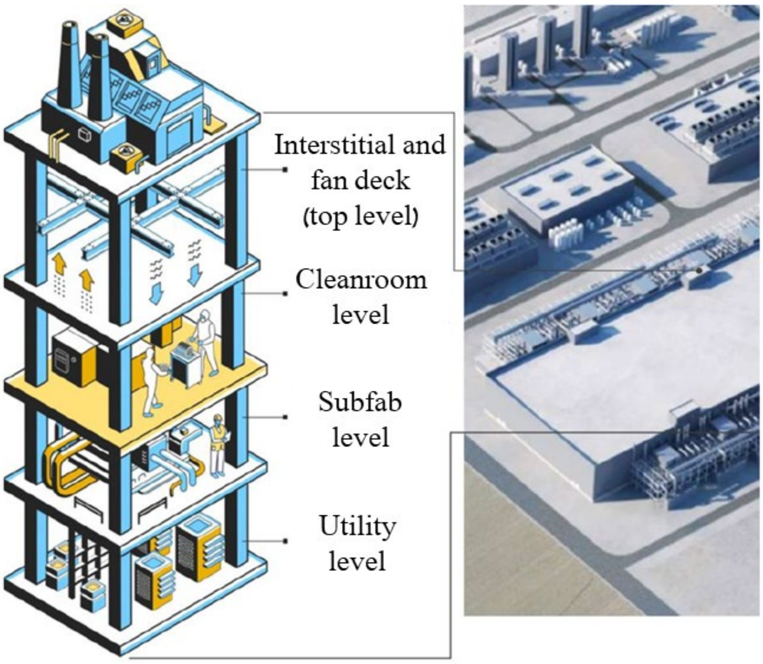

Figure 3: An Illustration of the Work Locations in a Semiconductor Fab

RESULTS

CYCLE TIME REDUCTION

OCF strategy has a positive impact on individual project CT within the portfolio, as illustrated in Figure 4, which presents the normalized durations for each project in the two portfolios. By applying OCF principles at the single project level - such as setting reduction targets, initiating projects only when all prerequisites are met and resources are available – production flow is smoother, resulting in shorter and more predictable CT. The production performance metrics (summarized in Table 2) reveal the significant improvements achieved through OCF Batching. Considering the same number of projects in both Pre-OCF and OCF portfolios (380 projects each), the OCF portfolio exhibited up to a 68% reduction in total project working days - from 25,359 to 8,176. This reduction in durations is reflected in the average CT per project, which decreased from 66.7 working days to 21.5 working days.

Figure 4: Cycle-Time Reduction with OCF

Table 2: Cycle-Time Reduction with OCF

	Number of Projects	Total Duration of all Projects [Working Days]	Average Cycle-Time [Working Days]
Pre-OCF	380	25,359	66.7
OCF	380	8,176	21.5

WORK IN PROGRESS REDUCTION

With the OCF Batching implementation, the second portfolio was organized into 16 batches. Comparison of WIP levels between the Pre-OCF and OCF portfolios reveal a substantial improvement in production performance. In the Pre-OCF portfolio (Figure 5, marked in a dashed red line), WIP levels increase rapidly to a high peak of 81 projects, reflecting the traditional push-based approach, as projects are initiated "as soon as possible", regardless of their maturity level. The high peak and large area under the WIP curve in the Pre-OCF phase indicate both high WIP levels and longer CT at for each individual project.

In contrast, the OCF portfolio (Figure 5, marked in green) shows a more controlled and balanced WIP level due to the implementation of a pull-based, batch-driven strategy. By introducing projects only when prerequisites are met and resources are available, the OCF approach shortens the CT for individual projects. This reduction in CT means each project spends less time in active WIP. Consequently, the WIP peaks in the OCF phase are lower and more consistent, leading to a smaller area under the curve. The reduced area reflects the efficiency of the OCF system, that gradually enables the fab to meet production capacity milestones reliably on time.

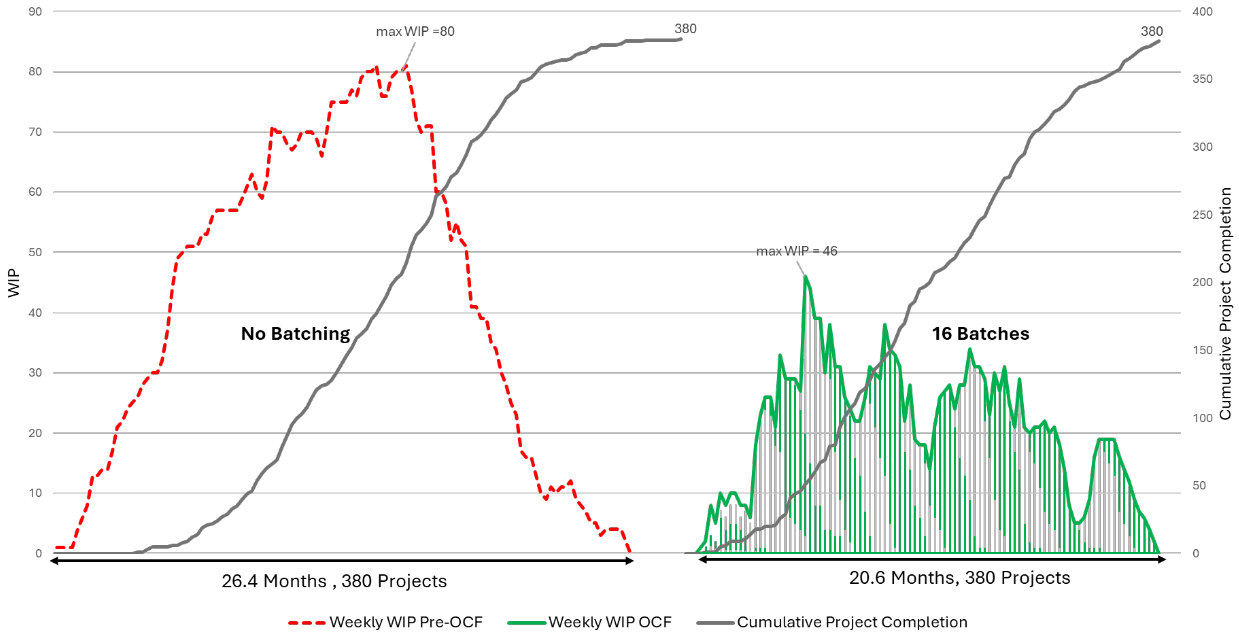

Figure 5: Work-in-Progress Reduction: no Batching vs. 16 Batches

DISCUSSION AND CONCLUSIONS

OCF Batching introduces a novel approach to PPM by combining the concept of batching with the strategic objectives of OCF to optimize organizational performance. While traditional manufacturing-oriented batching methods focus on operational efficiency, OCF batching integrates strategic cycle-time reduction targets for each individual project, and a goal to double the throughput at the organization level.

Takt planning, recognized for its ability to synchronize work tasks within a single project and achieve a steady and reliable production system, serves as a valuable framework for managing workflow and avoiding delays. OCF Batching complements takt planning by expanding its application to the portfolio level, combining project grouping strategies with targeted CT reduction goals. This approach builds on the strengths of takt planning while adding a layer of global optimization that ensures both reliability and scalability across a portfolio, enhancing system-wide performance.

In the case study presented in this paper, the impact of OCF Batching on production performance metrics was as follows:

1. **CT Reduction:** As shown in Figure 4 and Table 2, the implementation of OCF Batching resulted in a 68% reduction in average CT (from 66.7 to 21.5 working days per project).
2. **WIP Reduction:** Figure 5 reveals a significant reduction in peak and average WIP levels. In the pre-OCF phase, high WIP levels (peak of 81 projects) led to resource bottlenecks and longer cycle times. In contrast, OCF Batching maintained balanced and controlled WIP levels (with a minor peak of 46 projects), enabling predictable project flows and stable resource allocation.
3. **Steady Workflow:** The varied and well-mixed batches ensure continuous engagement of trades across projects and locations. The combination of both long and short projects within different locations reduced idle time and optimized trade utilization. While the scope of the current paper precludes an in-depth analysis of the project mix in each batch, it is evident from the results that this balance played a critical role.

While external factors such as trade availability and experience, and supply chain stability, could have influenced the outcomes, we believe the improvements observed are primarily due to OCF Batching. As outlined in the research methods, both portfolios were relatively similar in terms of projects scope, resource availability, and market conditions.

The pull-based nature of OCF Batching contrasts with the traditional "push" approach, emphasizing readiness and constraint removal to ensure that only mature projects are pulled into batches. Unlike LPS, OCF Batching is specifically tailored for portfolios of projects, aligning project readiness filtering with strategic organizational goals to reduce overall time-to-market for critical production milestones while optimizing resources and reducing variability. By integrating customer priorities and trade capabilities, OCF Batching ensures alignment between production schedules and client requirements, achieving a balanced and strategic approach to PPM. Constraint management, a cornerstone of OCF Batching, is addressed through iterative planning cycles that continuously evaluate locational constraints and resource limitations to balance resources, prevent overloads, and maintain the feasibility of each batch. This process, comparable to the LPS make-ready process, emphasizes the identification and resolution of physical and informational constraints before execution, extending the make-ready process to the portfolio level and enabling systematic adjustments to batch plans that enhance predictability and flow.

FUTURE RESEARCH

Despite its demonstrated benefits, OCF Batching requires further exploration. While the approach effectively integrates principles of pull, constraint management, and resource utilization, the aspects of project mix within each batch remain unexplored in this study. Investigating the optimal combination of long and short projects, including the influence of project complexity and trade requirements, could provide valuable insights that can enhance performance. Additionally, the mathematical formulation of the batching problem represents a significant area for future research. Developing a robust framework for this purpose would enable the use of advanced analytical methods, such as optimization algorithms or artificial intelligence models, to generate more efficient batch plans.

Further research could also focus on applying OCF Batching to other types of construction portfolios, such as residential buildings or infrastructure projects, to validate and enhance its applicability. Exploring how OCF Batching adapts to portfolios with high variability in project types, durations, and resource demands would enhance its utility across a broader range of construction scenarios. Additionally, the relationship between OCF Batching and LPS at the portfolio level requires further refinement. Investigating how OCF Batching enhances LPS principles, such as lookahead planning and the make-ready processes, could lead to the development of a cohesive lean methodology for PPM.

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