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REPEATABLE, SCALABLE, GLOBAL IMPLEMENTATION OF OPTIMIZED CYCLE-TIME FLOW (OCF)

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ABSTRACT

Optimized Cycle-Time Flow (OCF) is a comprehensive lean construction approach to portfolio, process, and operations management of design, demolition, and tool installation projects. It comprises seven principles which teams can implement in sequence to align resources across a portfolio of projects, remove constraints, and plan for continuous uninterrupted execution of each project once it has started. Beginning in 2018, it has been applied to increasingly larger portfolios of projects in an expanding set of Intel facilities, generating consistently reliable results with up to 50% reductions in project cycle-time. A plethora of quantitative data collected through action research over five years indicate that the characteristics of OCF make it more resilient and persistent than many lean construction interventions, overcoming the various barriers to implementation discussed in the literature. The results indicate that OCF principles, vertical integration, leadership, and education make OCF repeatable and scalable. Applying these features to lean construction implementations may help practitioners achieve better results.

KEYWORDS

Action Research, Constraint Management, Last Planner® System, Optimized Cycle-Time Flow (OCF), Production Control, Strategic Integration & Planning

INTRODUCTION

Optimized Cycle-Time Flow (OCF) is a comprehensive approach to portfolio, process, and operations management of projects developed and tested within Intel Corporation at several worldwide fabs. Tool installations are short-term construction projects with very high product and process complexity. A typical semiconductor fab tool has tens, sometimes hundreds, of connections to infrastructure and material supply systems.

OCF is an improved version of the original Optimized Installation Flow (OIF). OIF achieved a 48% average cycle time reduction on a portfolio of 75 projects and 42% on 33 projects (Gabai and Sacks 2020). Gabai sought to explore whether cycle-time reduction could be scaled from the Project Implementation Team (PIT) level to the program level to learn how to better improve the system and its application through action research (Azhar et al. 2010; Lewin 1946). As is common in action research, Gabai was immersed in repeated cycles of

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devising the system, applying it in practice, evaluating the outcomes of the action, and improving it according to learning. The objectives of the research were to determine the degree of OCF impact to which it might contribute to reducing project cycle-times and to identify which aspects that make it resilient and scalable in implementation.

To date, OCF and OIF have been implemented on more than 1,700 projects at Intel fabs, in portfolios of ~300 at Kiryat Gat in Israel and ~1,400 at Intel's fab in Arizona, supporting a unique longitudinal action research effort. The wealth of experience and data collected enabled analysis of the mechanisms behind its success manifested primarily in a reduction of cycle-time of some 50% across the portfolio with significant productivity gains for trade crews. In this paper, we describe the challenges faced and review data to highlight ways in which this lean construction innovation was scaled and implemented without loss of focus, degradation of the practice, or the results over time.

OIF/OCF ORIGINS

In 2018, Doron Gabai (the lead author) was assigned to lead a subprogram with Intel Corporation construction teams. He managed three project managers, ten construction coordinators, and five hundred subcontractor trade personnel - from process-mechanical, dry-mechanical, electrical, and architectural disciplines. Although Gabai ostensibly had mature teams that previously worked together and well-defined project scopes consisting of repetitive tasks with the latest tools and techniques - his projects continued to finish late with abound excuses and unpredictable results. He was forced to request and apply acceleration actions. In retrospect, most of the mishaps could have been avoided if strategic planning had been in place to enable PIT members to catch them in a timely manner. Repeated production failures became stressors to Gabai's teams and blighted his professional track record. Gabai's mission to empower his teams to achieve their best was failing. He disliked reporting weekly failures and sought a better way - a new strategy that would:

Benefit both project stakeholders and PIT

Resolve constraints prior to production

Start a project only when ready

Not allow late production

Not allow stopping after a project has started

Consistently produce success and optimize flow

Gabai and his PIT began experimenting with planning strategies derived from the Last Planner® System (Ballard 2000; Ballard and Tommelein 2016), Strategic Project Leadership (Shenhar 2015), the Theory of Constraints (Goldratt and Cox 2016) and the Portfolio, Process and Operations (PPO) model (Sacks 2016) depicted in Figure . OIF integrated two project management principles (*strategic integration planning* and *target tactical planning*)**,** two LPS steps (*collaborative planning* and *constraint management*)**,** two measures design to ensure project flow at the portfolio level (*control installation start* and *ensure continuous installation*) and an emphasis on *prefabrication* (Gabai and Sacks 2020). OIF was tested on a set of 199 projects over a period of 18 months from July 2018 through December 2019. Intel teams successfully reduced installation cycle-times by 42% to 48% without adding additional resources or acceleration. This was measured as actual installation project start-to-end durations divided by planned durations, as recorded in Primavera P6. The name changed from OIF to OCF when the system operated on a portfolio level and reliably reduced cycle times when portfolios of multiple projects of a variety of types were planned in concert.

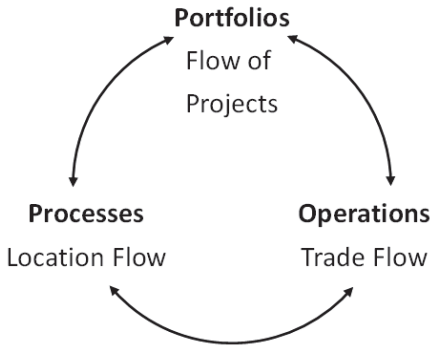


Figure 1: PPO Model - cyclical view of the relationship between project portfolios, processes and operations (Sacks 2016).

WHAT IS OPTIMIZED CYCLE-TIME FLOW (OCF)?

OCF applies seven principles to optimize flow of projects within an organization's portfolio while simultaneously reducing cycle-times and resources. It reduces the number of work-in-process (WIP) through a combination of prefabrication and constraint clearance filtering. This optimizes process flow through sound structuring of resources, task allocations, and multi-trade collaboration. OCF also applies organizational learning to maintain and repeat practices of this workflow for future projects. The Flywheel in Figure 2 depicts the seven principles. Six out of the seven principles emphasize deliberate serve as overarching strategic integration and planning that propel the flywheel. The arrows in the middle of the flywheel – trust, value, innovation and knowledge – help build and maintain flow. Achieving a reliable flow of projects and processes is one of the explicit goals of OCF and enables predictable project delivery. The principles collectively implement strategic integration and planning to enable a thorough production start in principle seven.

OCF Principles:

1. Plan & Integrate Strategically
2. Plan Tactical Targets
3. Collaborate
4. Resolve Constraints
5. Restructure Resources
6. Control Project Start
7. Ensure Project Flow
5.

Figure 2: Optimized Cycle-Time Flow Strategy for management of projects

The sequential order of OCF principles establishes the planning and control of workflow for all stakeholders involved, from executive-level teams to production teams. Each principle requires an immediate action and builds upon the prior principle onward into the start of production in Principle VII. Table outlines the intended outcomes of applying principles within an OCF batch in a project to enhance the flow of a program portfolio. Six of the seven apply to the planning phase, which emphasizes the importance of deliberate planning.

Table 1: OCF Principles and intended outcomes.

Principle No.	Principle name	Intended outcome	Project phase
I	Plan & Integrate Strategically	Align project strategy with organizational strategy, establish 50% reduction of both cycle-time and resources	Initiation & Planning
II	Plan Tactical Targets	Written plan with percentage duration reduction target	Planning
III	Collaborate	Stakeholders' commit to OCF targets	Planning
IV	Resolve constraints	Proactively identify and resolve resource, information, procedure, material, labor, and space constraints	Planning
V	Restructure Resources	Shift skills/activities off critical path/project	Planning
VI	Control Project Start	Start only when ready by re-evaluating checklists	Planning
VII	Ensure Project Flow	Execute and maintain flow using one dedicated team "Touch the Project Once"	Execution & monitoring

OCF was developed in response to numerous problems observed in prevailing project management practices. Like many other lean construction interventions, it conflicts with existing behavioral patterns that are deeply ingrained in the traditional culture of construction. This requires paying careful attention to hearts and minds, as workforce and managers need to reset deeply-rooted ideas about production planning and control. The problems that were observed and ways in which OCF principles address them are detailed in Table .

Table 2: Production problems observed during 2018-2022 in two sites and the OCF approach to ameliorating them. Relevant OCF principles are listed in parentheses.

Problem	Description	OCF strategy
Multi-Projecting (project WIP)	Teams often struggled to work simultaneously on up to eight different tool installation projects in different locations	OCF assigns one project per team at a time. Allowing a team to focus on one project reduces distractions and overworking the PIT (*Strategic Integration & Planning, Project Flow*)
Optimism Bias and Parkinson's Law	Much time is wasted and/or unreasonable deadlines are set. Targets are set, but not discussed with the teams who are performing the work.	OCF requires ongoing collaboration between the PIT and stakeholders during strategic integration and planning; input from the PIT is solicited, valued, and shared with stakeholders (*Target Tactical Plan, Collaboration*).
Wasted Work	Teams do not finish what they started without changes and/or multiple interruptions (e.g., waiting for materials, waiting for crews, waiting for approvals)	The PIT's skill and expertise are respected and applied for constraint filtering. Projects start only when make-ready checklists are complete. OCF's six planning principles are preventative discussions that enable uninterrupted project execution and prevent rework (*Constraint management, Project start*).
Competing Priorities	Every task in a project is considered "high priority". This leads to provision of resources to complete the tasks, which denies resources from other tasks.	Knowing true priorities reduces stress on the PIT. OCF applies readiness tools to label priorities: OCF batching matches resources demonstrated capabilities with the right priorities (*Strategic Integration & Planning*).

Problem	Description	OCF strategy
Constant Change	Change in project scope is prevalent due to market demands (the need to keep ahead of competition). Most often change is introduced during a project surprising and disrupting teams' performance	OCF enables a competitive edge by reducing cycle-time. This allows freeze of scope: when a PIT starts project *i*, the scope of project *i+1* is frozen. Changes can still be made only in OCF batch *i+2* subject to thorough application of make-ready checklists. Thus, OCF establishes a stable and predictable way to introduce innovations and changes for the PIT (*Strategic Integration & Planning, Project Start*).
Inefficiency	Project 'acceleration' actions lead to inefficiency because they force trade crews to move resources from project to project, interrupting other projects in unpredictable ways.	OCF avoids accelerated work schedules that overwork the PIT and establishes consistent and ongoing work for the PIT to complete (*Strategic Integration & Planning, Project Flow, Throughput formula*).
Task Force Mode	Priority projects are assigned exclusive resources, disrupting PITs.	The OCF batching team proactively removes constraints with PIT and stakeholders' assistance, eliminating the need for 'Task Force Mode' (*Project Flow, Strategic Integration & Planning*).
Lack of Incentive	No incentive to finish projects early; we typically have not acknowledged PITs for finishing a project early	Finishing projects early and reliably give PIT time for a break and helps avoid stress. Early finishes are recognized and rewarded (*Project Flow, Strategic Integration & Planning*).
PAS Start valued more than PAS Finish	Start Progress (or Performance) Against Schedule (PAS) was prioritized. Teams were frequently successful at starting, but less frequently succeeded in finishing on time.	OCF does not allow projects to start unless ready and enables successful completion. PIT can be assured that once they start, they will finish (*Project Start, Project Flow*).
Multi-Tasking	PIT trade crews work on multiple tasks simultaneously and priorities often change. Often when welding or bending pipes, for example, teams are sent to work on different tasks (fetching materials, for example).	OCF does not allow changes to task assignments during production and enforcing make-ready conditions means the PIT can consistently complete tasks with repeatable results. This also reduces safety risks and improves quality (*Strategic Integration & Planning, Restructure Resources*).

Extensive data obtained from OCF implementations (Freeman 2022a; Miera et al. 2021) indicate the following measurable and quantifiable benefits of OCF:

1. **Increased Organizational Throughput:** Reduced project cycle-time improves project throughput in accordance with Little's Law, allowing control of work in progress (WIP). Overall, schedule execution is reduced by eliminating constraints and idle times in the strategy. This is achieved without acceleration.
2. **Predictable Delivery Performance and Execution:** OCF provides a visual representation of current projects and prioritizes OCF batches based on customers' needs through predictable delivery performance.
3. **Improved Cost Control & Cash Flow:** Reduction of the cost of resources due to reduced waiting and continuous work, thanks to strategic planning of project batches and improved schedule predictability and reliability. Resource demand is leveled, avoiding peaks that degrade productivity.

4. **Change Control:** Rather than apply innovations via short-term project scope changes. Innovations are introduced in i+2 OCF batches. This prevents interruption and disturbance to the workflow of the majority of projects.
5. **Efficient Decision Making:** OCF batching decisions are made in collaboration with project customers and support stakeholders, freezing and prioritizing per customer needs.
6. **Shorter time to market:** The overall value of the strategy when applied broadly is to reduce the time needed to bring new products to market.

The associated qualitative benefits to the company and different stakeholders include enhanced competitive advantage, operational excellence, improved communication and increased internal customer satisfaction.

EXPANDING IMPLEMENTATION

Expanding and implementing OCF required overcoming barriers identified in the literature (Bølviken and Koskela 2016). A recent study highlighted a lack of support and commitment from top management as a barrier (Moradi and Sormunen 2023). Gabai faced multiple challenges when scaling and expanding OCF beyond Israel to Arizona. However, working with co-authors Miera and Cloyd, Gabai and his team were able to demonstrate production results with sufficient throughput improvement to convince top management that OCF succeeds in engendering vertical integration. They were guided by Kotter's eight steps for leading change (Kotter 2012, Fig. 2-2 p. 23). In the OCF context, this involved:

1. Emphasizing the urgency of implementing tool installations effectively to provide a competitive edge in semiconductor fabrication.
2. Convincing management that the OCF strategy was an effective solution and explaining the benefits to PITs through their lenses.
3. Formalizing the OCF strategy and documenting it clearly.
4. Identifying and equipping OCF Champions to lead teams.
5. Convincing PIT members, both employees and subcontracted trade crews, to take the risk necessary to change their patterns of work.
6. Generating and celebrating early wins – work with the most promising candidates in each PIT, experiment with OCF to gradually optimize 50% cycle-time reduction.
7. Promoting ongoing learning and education of OCF goals per project through team collaboration, measuring results and assessing production flow for improvement.

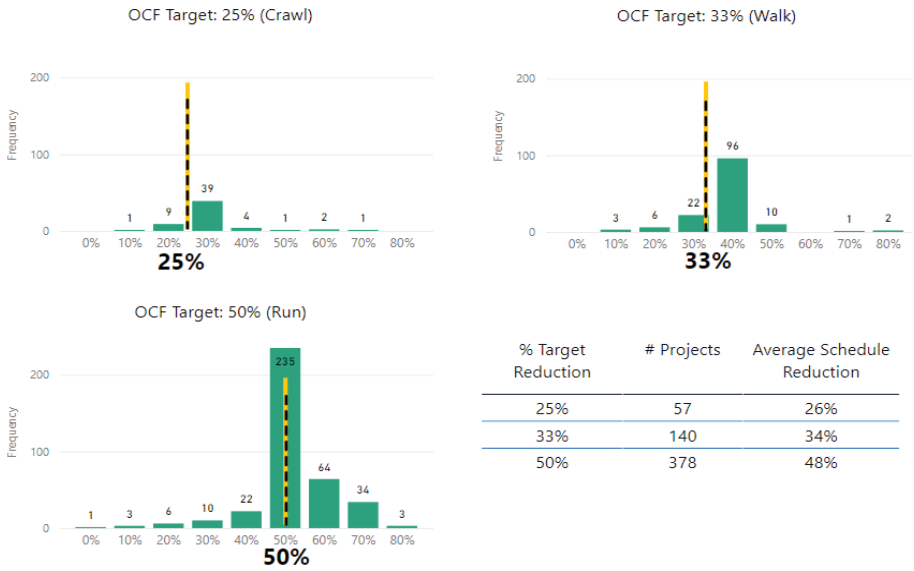
Nevertheless, finding willing partners among project managers and production teams proved exceedingly difficult. Gabai leveraged the experience of five fearless early adopters (Montoya, Yalung, Bambauer, Miller and Lempert) – all project managers with whom he worked previously (Freeman 2022b). He met with trades and other subject matter experts (SMEs) within their PIT to engage them. This resulted in an initial set of 48 projects with an average of 48% reduction in cycle-times.

Gabai devised a strategy for the broad implementation of OCF, answering such questions as: What would the throughput look like? What are the cycle-time benefits for the program? A careful analysis of implementation barriers across teams served as possible solutions to guide this effort. The analysis is detailed in Table .

Table 3: Barriers to OCF implementation in Arizona and solutions applied.

Barriers to OCF implementation in Arizona	Strategic OCF Solutions
Contracts from previous projects set the tone for doing things the same way. Convincing trades that OCF was different to current practice, where only Last Planner® was used, was challenging	Help people understand the current reality and see the future, building a shared vision, making incremental improvements, and asking what needed to be done to make this successful. The small wins when the team hit 25% (crawl) and 33% (walk) aiming toward 50% (run) targets were celebrated – building trust.
Culture of the project ecosystem. Each team believed that others were the constraints.	Formed a coalition of the willing – following Kotter's 8th step. This is the foundation of vertical integration. We established an OCF Program Batching team that met daily to continually communicate the vision, remove obstacles.
Threading various groups together. Lack of cohesiveness, multiple teams working in silos. Focus on local optimization.	Team leaders understood that OCF was unlike other strategies. They learned that OCF is not simply tactics or objectives, and they may have recognized parts of OCF in previous initiatives such as IPD or Last Planner® System. They learned to avoid selective implementation and implement all seven principles to yield disruptive change.

OCF was performed with four PITs in 2020, and this grew to eight Arizona PITs that included design teams during 2021 and 2022. The Arizona team developed a strategy to halve the project durations using a crawl, walk, run, methodology. As each new group of trade partners was introduced to OCF, they initially set a target of a 25% reduction in duration. This allowed gradual onboarding of new trades to experiment with the owner and develop trust over time while applying the new strategy with a less demanding target. As project managers and PITs learned and grew in confidence applying OCF, targets were adjusted to a 33% reduction of duration for their next set. Finally, a set of 378 projects was given a 50% target reduction rate. Figure shows the distribution of outcomes. The 57 projects with targets of 25% achieved an average of 26% schedule reduction in practice. The 139 projects with 33% targets achieved 34% and the 139 projects with 50% targets achieved 48%. Table shows the expanding number of projects.



% Target Reduction	# Projects	Average Schedule Reduction
25%	57	26%
33%	140	34%
50%	378	48%

Figure 3: Distribution of duration outcomes for crawl (25% target reduction in duration), walk (33%) and run (50%) projects sets.

Table 4: Expansion of OCF to Intel's Arizona PITs (quantity of discrete projects).

Project type	2020	2021	2022
Demolition	-	281	220
Design	-	230	105
Tool Installation	48	307	268
Total	48	818	593

Over time, the Arizona OCF program yielded five times as many projects as Israel and demonstrated a 233% throughput improvement compared to non-OCF projects for Intel Corporation. Table lists the cumulative total project durations over five years. This was made possible thanks to vertical leadership and upper management changing the ecosystem culture from the top down in the organization in terms of planning and executing OCF projects. At the time of writing, the company has completed more than nineteen batches of OCF projects reducing costs and substantially enhancing revenue for Intel benefitting subcontracted trades and third-party teams. We have annotated three anecdotal comments from PIT trade members below saying the following:

> "This [OCF] program definitely shows a nice level even flow of work without the spike in manpower…that's what I got out of it."
>
> "All of us trade partners – the majority of us were doing well on the performance side but, every once in a while, there was a supplier or equipment delay. That's where we found our biggest challenge because then it's a domino effect on batching. So, everyone has to perform 100% for the batching to be 100% successful. I definitely felt like this last ramp that we went through was smoother."
>
> "Schedule wise it was successfully compared to previous ramps for sure and the profitability side you know…we did not lose money overall, the teams definitely liked the [OCF] batching program – the "get it done before we start a new task." They definitely preferred, enjoyed and liked that method of scheduling. So we're on board with this, this OCF concept for sure."

Table 5: Cumulative total project durations in days for OCF implementations of tool installation and demolition projects - baseline plan, OCF target and OCF actual days.

Baseline Plan, Target, Actual	2018 ISR	2019 ISR	2020 ISR & AZ	2021 ISR & AZ	2022 ISR & AZ
Baseline Plan project days	1,057	3,996	3,969	16,231	11,321
OCF Target project days	826	2,753	2,422	8,357	6,572
OCF Actual project days	502	2,288	2,129	8,775	6,674
% Reduction (Actual vs. Baseline)	53%	43%	46%	46%	41%

DISCUSSION

Organizations must adapt to be innovative to meet current and future demands. These innovations require projects to be better optimized for them to deliver new products or services. Hence, many organizations run portfolios of numerous projects and programs in parallel. To yield outcomes that lead the market, an organization's ecosystem should enable setting the right priorities for compatible resource allocation so that the goal of the projects can be done in shorter and more predictable cycle-times ahead of competition.

Considering the barriers to the implementation of lean construction innovations and Kotter's steps for organizational change, the OCF team at Intel focused on preparing leadership by highlighting and publicizing potential benefits to educate PIT teams - taking proactive steps to remove barriers to lean construction implementation.

Leadership and Education

OCF has garnered engagement from top management because of active participation mandated beginning with principle number one to completion to strategically plan with a commitment to the schedule and needed resources to optimize 50%. OCF is not deployed successfully without vertical leadership support and recognition of mutual benefits for both the organizational and PIT ecosystems. Thus addressing Moradi and Sormunen's (2023) findings on lean barriers. OCF Champions, stakeholders, etc. must fully understand the organizational benefits of OCF in conjunction with the benefits of OCF for the PIT prior to attempting strategic integration and planning discussions. This helps everyone understand the "why" and the need for such a holistic production strategy.

Collaboration and the component of mutual benefits for everyone (i.e., the customer, production, and organizational teams) were focal points for reiterating the crawl, walk, run optimizations of OCF cycle-times. Miera, Cloyd and Gabai coached PMs to keep crawl, walk, run in mind as they developed target pull plans for their OCF batches. PMs had to adapt to new targets based on the OCF batch; applying Principles I and II which helped to identify OCF Champions – team members who fully grasped and accepted the strategy. Next, an OCF batching team of leaders from Intel, internal customers, and PITs worked side by side to devise an inclusive strategy at all levels of program implementation to address:

Why are we doing this?

What is the shared vision that will inspire and challenge our teams?

Are we freezing the scope?

Do we have an up-to-date target tactical plan?

How do you turn common field constraints into a pre-defined constraint checklist?

Are we really ready to start?

Can we start and not stop?

Barriers to Lean implementation

Many publications point out the difficulties that implementers of Lean Construction face (Bølviken and Koskela 2016; Moradi and Sormunen 2023). Lack of definition of what constitutes Lean Construction hinders both adoption and sustainable implementation from managers and crews often not having a clear idea of what is expected of them (Leong et al. 2015; Pasquire 2012). Mano et al. (2020) provide a useful meta-analysis of the literature. From some 400 causes identified, they isolated eight key barriers to Lean Construction implementation: (1) lack of commitment in the team, (2) difficulty in obtaining support and commitment from upper management, (3) resistance to change from leaders, (4) difficulty in centralizing the focus of the client's business, (5) resistance to change from employees, (6) inability to measure the progress of the Lean project, (7) decision centralization, and (8) lack of preparation by the managers to conduct the change. Six of the eight relate to leadership, and three highlight the need for a solid base amongst company leaders prior to deployment. Reflecting on our action research taken to expand implementation of OCF and subsequently to other Intel sites in the US, Far East, and Europe, one can identify how OCF defused barriers. Appendix A outlines the barriers identified and discusses how the comprehensive strategy ameliorated those barriers.

CONCLUSION

OCF implementation started with Doron Gabai attempting to bring predictability and order to the project portfolio of one Intel PIT. In doing so, he created added value for the team, for Intel stakeholders and for subcontracted suppliers. The OCF journey continues, with expansion of adoption within Intel and beyond. At the time of this writing there are three OCF sites (Israel, Arizona, and Oregon), each at a different point in their OCF journey, applying OCF to four different project types (tool install, demolition, design, and progressive build). More than 1,700 projects have been successfully delivered ahead of schedule without adding resources, funds, or time.

The barriers authors encountered mirror those identified in the literature, with leadership ranking as the top barrier. We propose the OCF strategy as a means to overcome barriers and deploy Lean Construction to project portfolios reliably, consistently, and predictably. Among the key aspects that enable OCF to achieve changed beahviours reliably are a) a set of formally defined and standardised steps that must precede the start of any project, all aimed at ensuring continuous execution without stoppages; b) a conscious effort to level resource allocations across the portfolio of projects, avoiding overloading of any critical resources; c) setting of aggressive targets for cycle-time reduction up to 50% in full implementation when compared with accepted practice, which preventing reliance on incremental adaptation in favour of the thorough fundamental realignment of the project execution strategies of PITs.

The findings of this action research may contribute to researchers and practitioners seeking a formal framework to support scalable and reliable Lean Construction implementation.

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APPENDIX A: BARRIERS TO IMPLEMENTATION

Table 6: Aspects of OCF that address barriers to implementation of Lean Construction.

#	Barriers to Lean Construction	OCF Strategic Solutions	Main OCF Principle #
1	Lack of commitment in the team	All stakeholders commit to reviewing pre-OCF results and assessing the need for changes to implement OCF strategy	I & III
2	Difficulty obtaining support and commitment from upper management	Collaboration and vertical integration commitments	I & III
3	Resistance to change from leaders	Organizations are made aware of resistance from any stakeholder as being a direct constraint	III & IV
4	Difficulty in centralizing the focus of the client's business	A clear picture of the throughput formula (Little's Law) along with strategic integration and planning of the OCF visual batches, enables consistent workflow toward the target	I, IV, VII, & Little's Law
5	Resistance to change from employees	Resistance is a form of constraint. OCF depends on collaboration and creates transparency amongst teams to effectively assess use of skills and resources to collectively remove constraints. We identified ten benefits to the PIT, mainly reducing the workload and respecting and ensuring constraint-free project implementation through Go/No Go; start only when ready checklists	III, IV, V & VI
6	Inability to measure the progress of the Lean project	OCF offers a clear percentage target of 50% optimization of cycle-time in the strategic integration and planning principle and builds the target tactical plan from Little's Law, enabling successful project control of the project prior to starting	I, II, VI & Little's Law
7	Decision centralization	The OCF batching team governs the implementation and does not rely exclusively on a single authority, thus enabling flow while simultaneously meeting targets with key leaders across the trade disciplines	II, III, VI, VII & Little's Law
8	Lack of preparation by managers to conduct the change	OCF cannot happen without all teams on board. Crawl, walk, run is a proven approach to help PITs become familiar with the new culture.	I & III