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DOUBLING THROUGHPUT WITH OPTIMIZED CYCLE-TIME FLOW (OCF) STRATEGY

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ABSTRACT

Despite the availability of advanced managerial tools and technologies for project planning and control, projects failing to meet schedules and budget targets remains a common phenomenon. We argue that a root cause for these failures is the absence of strategic planning. Optimized Cycle-time Flow (OCF) is a strategy developed by Intel Inc., that enables teams to plan portfolios of projects subject to resource constraints and the principles of flow, while avoiding the pitfalls of the planning fallacy and unnecessary time-extensions. This paper presents a thorough exploration of OCF through a case study in a typical installation project, one of the first OCF implementations. Practical applications of the principles of OCF are explored through analysis of construction plans and interviews with key personnel. The paper provides supplementary observations and validation of empirical findings regarding the effectiveness of OCF. The multi-project environment and the sense of urgency to reduce time-to-market are recognized as a catalyzer for OCF. The case study highlights the importance of critical production thinking as manifested in the first two OCF principles: "Plan and Integrate Strategically" and "Plan Tactical Targets".

KEYWORDS

Constraint Management, Design Science Research, Last Planner® System, Optimized Cycle-Time Flow (OCF), Production Control, Strategic Integration & Planning, Target Pull-Plan

INTRODUCTION

Significant progress has been made in recent years towards the realization of Lean Construction (LC) for installation projects in Intel Corporation (Gabai et al., 2023; Gabai & Sacks, 2020). First, an organizational learning process was carried out to assimilate the basic principles and tools of LC, including the Last Planner® System (LPS). Later, in light of growing awareness of waste and the need to enhance value in a predictable way, additional improvement attempts were made, leading towards the development of Optimized Cycle-time Flow (OCF) strategy.

The theories and tools expressed in OCF are diverse, including Transformation-Flow-Value (TFV) (Koskela, 2000), Portfolio, Process and Operations (PPO) (Sacks, 2016), Theory of Constraint (Goldratt 1997; Goldratt et al. 2004), and LPS (Ballard, 2000). Over the following years, OCF yielded significant results, including successful implementation of pull scheduling

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at the organizational level, reductions in projects' cycle-times, and improved resource flow. Human capital played a central role, thanks to the commitment throughout the entire value chain, from production floor workers to senior managers. In addition, an international learning group was initiated, the "OCF Industry Tribe", with participants from a variety of AEC backgrounds and at different stages of OCF implementation at their projects and organizations.

OCF was developed in a unique production environment: a multi-project organization with a clear value proposition, portfolios of similar projects, urgent installations needed to enable factories to begin production, and a "clean room" environment requiring accuracy and cleanliness.

Previous papers on OCF (Gabai et al., 2023; Gabai & Sacks, 2020) reported remarkable empirical results, including significant cycle-time reduction and enhanced throughput (TH). This paper provides an exploratory investigation and analysis of the empirical results, aiming to improve understanding of how the principles of OCF work in practice, and so to set the stage for a discussion regarding the applicability of OCF to other construction domains, in the context of portfolio or single project management. A case study for OCF implementation on a typical installation project is presented, attempting to identify how the principles of OCF were expressed.

LITERATURE REVIEW

Optimized Cycle-Time Flow (OCF) is a strategy that was originated to benefit both project stakeholders and project implementation teams. The seven principles of OCF are derived from various proven theories and methodologies, that are reinforced and synergized as they are combined. OCF principles are composed of six planning principles and only one execution principle, which emphasizes the importance of up-front planning to achieve 50% cycle-time (CT) reduction, and to double the organizational TH.

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

The OCF flywheel (Figure 1) begins with Principle I - ***Plan and Integrate Strategically***, and Principle II – ***Plan Tactical Targets***. These two principles are based on the Strategic Project Leadership® (PSL) approach to project management (Shenhar, 2015), that emphasizes business and strategic thinking at the project level, and guides managers how to translate strategy into practical activities within their project. SPL optimizes business outcomes by deploying strategies that effectively address project complexity and rapid changes, ensuring alignment between project and organizational objectives. In the context of multiple project organizations, and based on the Portfolio, Process and Operations (PPO) model (Sacks, 2016), these two first principles address the flow of trades and operations upon portfolios of projects and target an organizational throughput improvement. This is reinforced once integrated with Transformation-Flow-Value (TFV) theory (Koskela, 2000), emphasizing value generation to the customer, and efficient production flow. At the outset of implementation of these principles, the stakeholders develop a Target Pull Plan per project that must align with the strategic plan for 50% CT reduction and optimized organizational TH.

Principle III – ***Collaborate*** – This principle also stems from PSL and emphasizes a cultural environment that must show respect and develop trust and integration within the project team. It is also related to LPS implementation (Ballard, 2000) and emphasizes the importance of collaborative planning to improve reliability and stability of the production system. In a multiple project environment, this collaboration also leads to formation of organic high-performance teams, composed of trades from several subcontractors, that flow from project to project (ensuring CT reduction and completing projects on time).

Principle IV – ***Resolve Constraints***, and Principle V – ***Restructure Resources*** – are based on the Theory of Constraints (Goldratt 1997; Goldratt et al. 2004) and aim to identify and alleviate potential bottlenecks in the system. These two principles reinforce the implementation of LPS as they enhance lookahead planning and the make ready process, focusing on either physical or informational constraints that limit the production system (Ballard and Tommelein 2016). In the context of project portfolio management, these principles are applied to ensure constraint removal on projects that are pulled for construction. In the construction phase, continuous efforts are made to identify and remove constraints that may evolve in real time. This requires full support from the back office (for design issues etc.), and enhanced involvement of senior management when ad-hoc decision making is required (including resource allocation) to enable smooth production flow.

Principle VI – ***Control Project Start*** – and Principle VII – ***Ensure Project Flow*** originate from the Toyota Production System (Liker, 2001) and include pulling project to production just-in-time and according to client needs. Only once everything is set in place, work can be performed without stopping until completion. Thus, projects are batched according to customers prioritization and their maturity level, enabling to level the Work in Progress (WIP), and the availability of resources to reduce cycle times (each OCF batch is reduced by 50% CT).

RESEARCH METHOD

As presented in previous studies (Gabai et al., 2023; Gabai & Sacks, 2020) and as demonstrated in the next section, empirical data indicates the effectiveness of OCF in terms of cycle time reduction. This case study provides a supplementary observation and validation of the empirical findings, enabling a deeper understanding of the working mechanisms of OCF at the individual project level. The case study approach was selected, as it "…allows the questions of why, what and how, to be answered with relatively full understanding of the nature and complexity of the complete phenomenon" (Voss, 2008). As OCF is an emergent practice, there is great importance to present detailed examples that may enable industry practitioners to evaluate the applicability of the method in their organizations and projects.

Information for the case study was gathered from two main sources.

1. Review and assessment of construction plans, in the format of excel spread sheets exported from Primavera P6, and documentation of target pull plan meetings in which the durations of each task were re-examined, and a revised plan was developed.
2. Semi-structured one-hour interviews were conducted with key personnel, including the project manager, the piping subcontractor, and the owner representative (the tool owner). The interviews included open questions regarding the application and influence of each of the seven OCF principles at the project and organization level. Additionally, interviewees were asked to elaborate on the assumptions and actions that enabled CT reduction.

DOUBLING THE THROUGHPUT

To provide context for the case study, this section presents preliminary empirical results from OCF implementation on over 1,700 projects to date. The case study applies a magnifying glass to one of these projects.

At the organizational level, OCF implementation was done in a pincer movement: from one side, reduction of CT at the single project level (as detailed in the case study), and from the other side WIP management via “OCF batching”, to ensure only ready and required projects enter the construction phase, considering the demonstrated capabilities of the production system. Figure 2 illustrates a non-feasible baseline plan (in red) with extreme peak points regarding WIP levels, compared to an OCF batching plan (in green) which provides stable WIP levels. Figure 3 presents a non-feasible baseline Gantt chart that illustrates the number of projects under construction at the same time, compared to an OCF batching plan, with 24 batches of projects. Once OCF batching is combined with targeted 50% CT reduction at the single project level, doubling the TH becomes feasible.

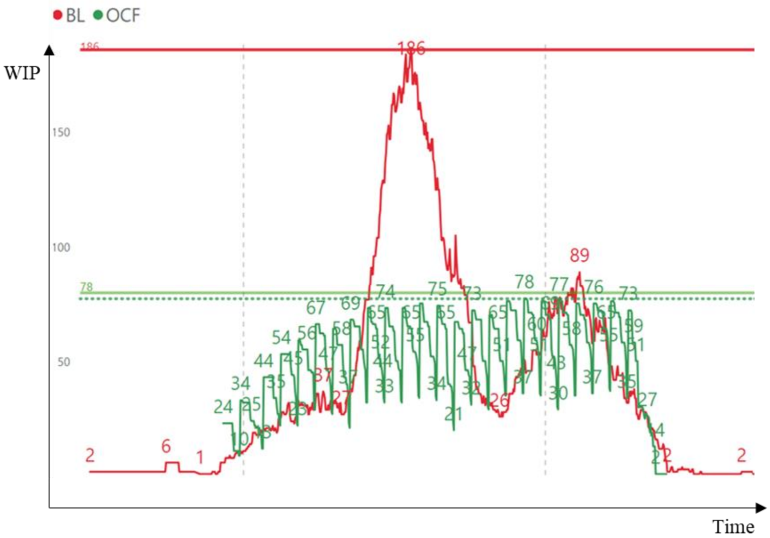

Figure 2: WIP levels of a non-feasible baseline plan compared to a OCF batching plan (Credit: Intel Corporation).

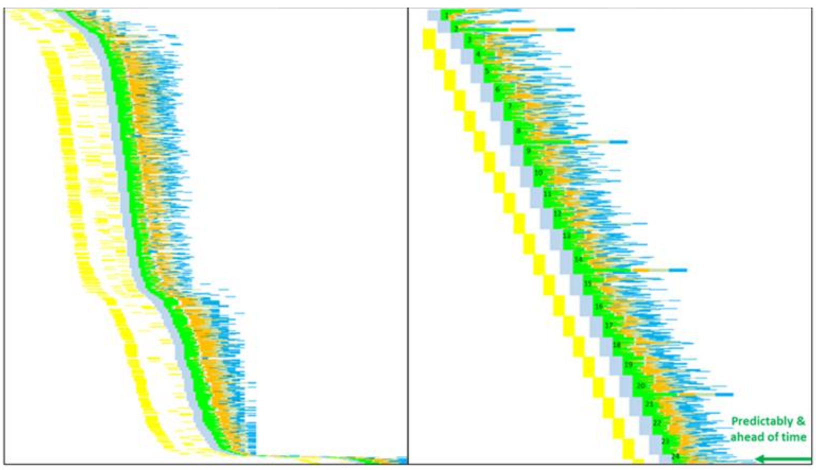

Figure 3: Gantt chart of a non-feasible baseline plan (left) compared to an OCF batching plan (right) (credit: Intel Corporation)

Figure 4 presents data analysis of 682 projects carried out from last quarter of 2018 till the mid of 2022. The red columns present the performance before OCF implementation (including accelerations taken in most of the projects). The green columns present the performance after OCF implementation, with a 242% improvement in TH and 59% reduction in CT.

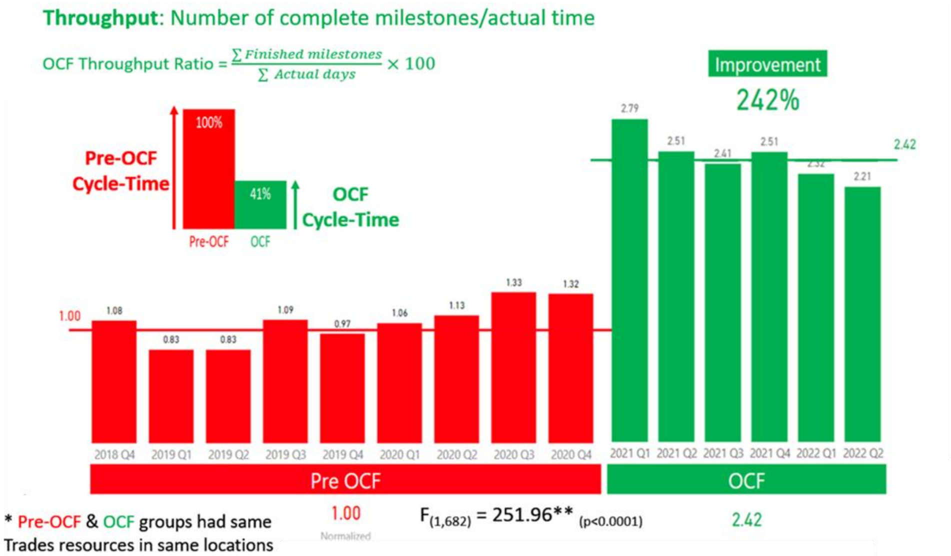

Figure 4: Doubling TH and reduction of CT by 50% after OCF implementation

CASE STUDY: OCF IMPLEMENTATION ON AN INSTALLATION PROJECT

BACKGROUND

This case study focuses on OCF implementation on a typical tool installation project in one of Intel’s fabrication factories. The factory, which is spread over thousands of square meters, includes over one thousand tools that must be installed at a millimeter tolerance level and must enable efficient space usage. In these projects, the factory in general and specifically each “tool owner” is referred to as the client, and value is measured through their lenses. Thus, a project that provides most value is one that is pulled according to production needs, meets specifications, and is carried out in minimal cycle times and disruptions to the production process.

The location breakdown structure of the project included three locations where work was performed: Level 1 – the Utility Level – contains electrical panels, utility pipes and ductwork that feed up to the sub fab; Level 2 – the Sub-Fab – contains pumps, transformers, power cabinets and other systems that support the clean room; Level 3 – the Fab or “clean room” – includes the tool itself and the interface with the products and workers on the production line. Figures 5 and 6 illustrate the three locations of the project, and Figure 7 illustrates workers at the clean room level (they wear “bunny suits” to maintain the sterile production environment). The construction scope herein is being done in all 3 levels mentioned above. Four main trades, from different subcontractors, took part in the project: Electrical, Piping, Ductwork, and Architecture-Carpenters. The trades worked in close coordination with the tool owner, who was also required to take actions at several steps in the process.

In general, the work breakdown structure of a typical tool installation project includes three main phases: Phase 1 – connection of the lateral lines at the sub fab to the clean room, according to the location of the tool to be installed ; Phase 2 – tool installation works at the clean room, that involve only non-dangerous gases and electrical charging; Phase 3 – tool installation works at the clean room, that involve dangerous gases.

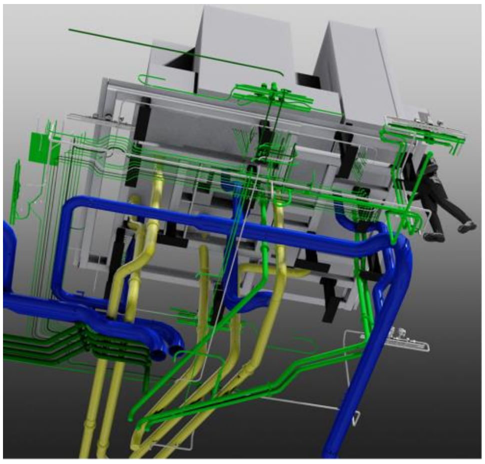

Figure 5: 3D perspective of the Sub-Fab and Fab level

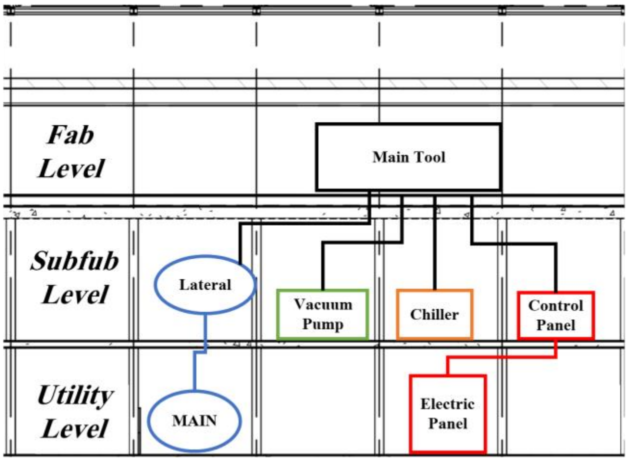

Figure 6: Location Breakdown Structure of installation projects at a typical Fab

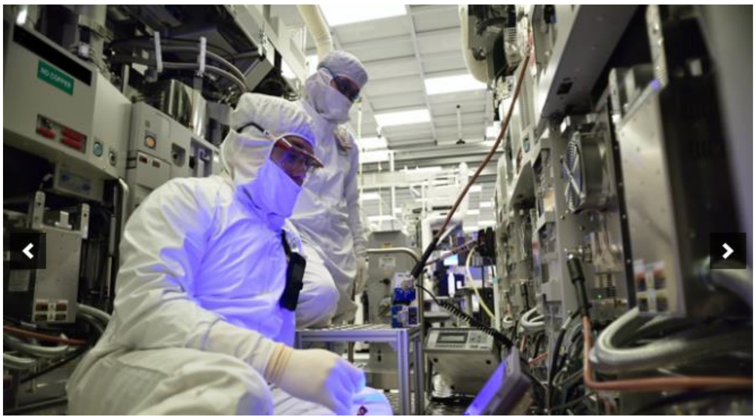

Figure 7: Installation workers at the clean room level of a Fab

CONSTRUCTION PLANS

The project was carried out using LPS and Pull scheduling, which were already implemented throughout the company's projects, and the teams were experienced in their operation. The preliminary plan, with a duration of 61 working days, is presented in Figure 8. During the application of OCF, a “Target Pull Plan” was collaboratively developed, to meet the company’s strategy to reduce installation projects cycle times. The Target Pull Plan, with a duration of 24 working days (CT reduction of 61%), is presented in Figure 9. Visual comparison between the plans highlights how the Target Pull Plan led a reduction in the duration and increased the work in parallel. It should be noted that the project was completed according to the plan, with a PPC above 90%.

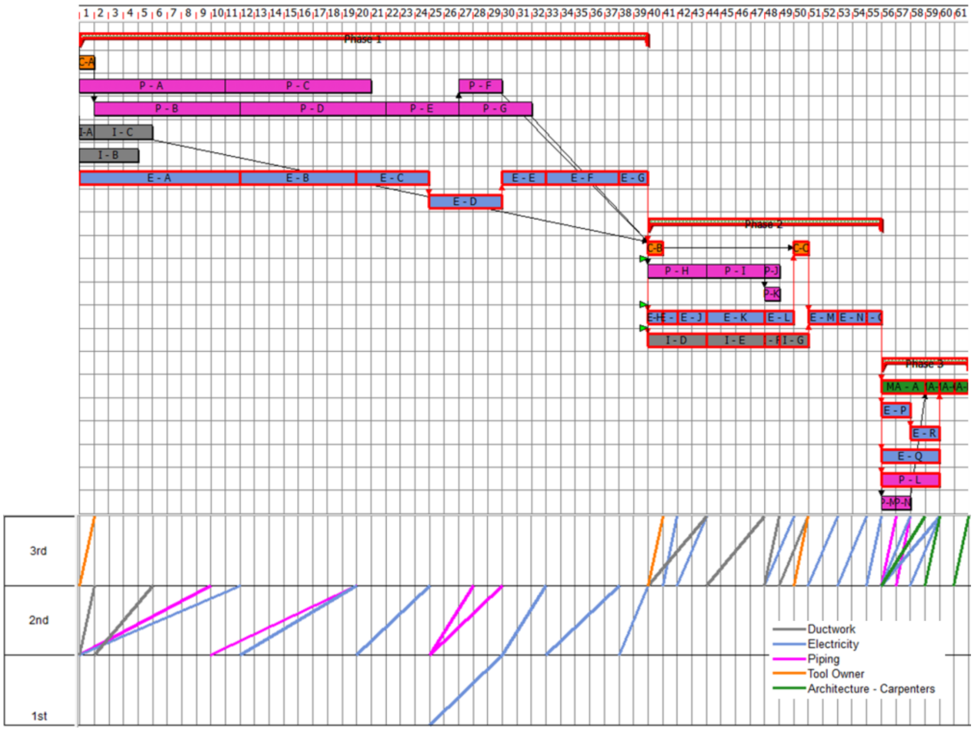

Figure 8: The preliminary baseline plan, before OCF implementation.

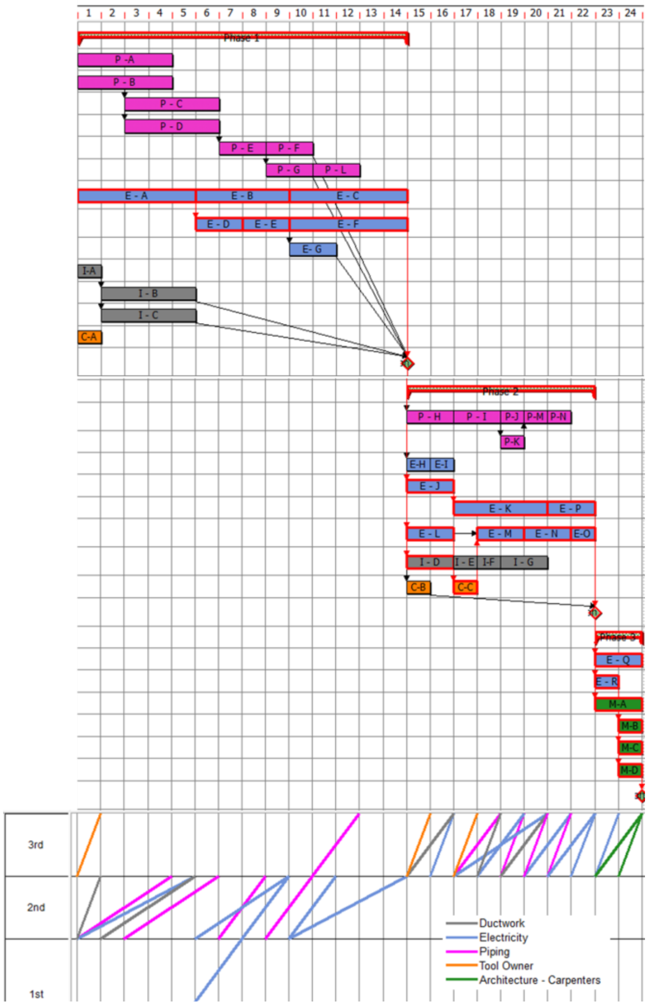

Figure 9: The 50% Target Pull Plan for OCF implementation.

IMPLEMENTATION OF THE SEVEN OCF PRINCIPLES

After the preliminary plan and the Target Pull Plan were compared, and illustrated the dramatic reduction in the project duration, semi-structured interviews were held with key personnel in the project to understand how the seven principles were implemented. The personnel interviewed included: the Project Manager (PM) from the construction division of the owner; the piping subcontractor (P-Sub), and the tool owner (the internal costumer). Interviewees were asked to elaborate on how each of the seven principles manifested at the project and organization level. In addition, they were asked to refer to the essential changes between the preliminary plan and the Target Pull Plan (Figures 8 and 9), and to describe how these changes were made possible. Highlights from the interviews, regarding each of the principles, are presented in the following sections.

Principle 1 - "Plan and Integrate Strategically": This refers to the organizational strategy to double the TH of completed installation projects, by OCF batching to control the WIP levels, and by setting 50% reduction target. Interviews highlighted that strategic planning was the core principle that initiated OCF implementation. The tool owner emphasized that completing the project with minimal CT, once all necessary preconditions are met, allowed early beginning of production in the Fab, thus increasing the competitive advantages of the organization.

The P-Sub admitted that at first, he thought this strategy would require investment of additional resources, but he took the leap of faith and "the results speak for themselves." In a pre-OCF environment, part of his business model relied on accelerations as projects were running late. With the long-term strategy, including OCF project batching (Figures 2 and 3), the piping company was able to maintain a stable, reliable cash flow, invest in well skilled trades, and undertake more projects per annum. He admits that "…with OCF and without accelerations, the profitability was improved and predictable".

All trades agreed that reducing the WIP enabled resources availability, and increased motivation to complete the project and move on to the next OCF batch. It also enabled them to generate greater value for the customer, who could start production earlier, and with minimal interruptions.

Principle 2 - "Plan Tactical Targets": The preliminary plan was revised, and a Target Pull Plan was collaboratively developed according to the strategy of doubling TH and reducing CT. As seen from the comparison of the preliminary plan and the target pull plan (Figures 8 and 9), a CT reduction of 61% was reached on this project. During the Target Pull Planning the trades were required to challenge the assumptions reflected in the preliminary plan, regarding both durations and feasibility to perform several tasks in parallel.

At the first stage, the team examined the feasibility that baseline duration estimates could be reduced if they could work on substantially fewer projects in parallel. Each trade was required to examine whether they could commit to shorten the durations by 33%, 50% or 80%. This approach led the trades to re-examine their work assumptions. In some cases, the answers were unequivocally negative. However, for a significant number of tasks, possibilities emerged as it became clear that long durations with inflated internal buffers were assumed in the preliminary plan.

At the second stage the logical connections between tasks were re-examined, possibilities for simultaneous work were considered, and an improved workflow sequence plan was developed. Once the trades let go of the limiting assumption that each trade must require a separate location for any work to be performed, the door was also opened for many opportunities to work in parallel. Thus, a "lean" production plan was established, relying on the targeted required durations, and sound logical connections. It should be noted that once the durations were reduced, some of the tasks gained a positive total slack, and buffer management became possible (Goldratt 1997; Goldratt et al. 2004). Additionally, production was shielded by limiting the number of concurrent projects (WIP) for each trade, allowing resource availability, enhanced motivation for early completion, and improved workflow for each trade, as well as earlier cash flows (because payments are approved upon completion of work).

Principle 3 - "Collaborate": This principle was brought up many times in interviews and in different contexts, highlighting its importance and lateral influence. Tight collaboration was shown by trades at the Gemba, senior management of the subcontracting companies, and by the tool owner. The PM demonstrated how trades coordinated their daily work at an hourly level of resolution, to enable a significant portion of work to be performed in parallel at the same location. Even lunch breaks were coordinated to enable trades to perform specific tasks that require the entire location, with minimal influence on other trades. Senior management collaboration was reflected by the back-office support, including agile ad-hoc design coordination when needed.

There were voices in the organization that questioned whether the extensive parallel work would align with the safety standards of the organization. However, as the P-Sub explained, the opposite was the case: the exposure to safety incidents decreased as the CT of the project was reduced; the collaborative approach led to an improved safety environment, as safety plans where tightened and coordinated; inputs were generated from the safety inspectors of each trade, enabling preventive actions ahead of time.

Collaboration was also the key for coordinating the work performed by the tool owner and the vendor, enabling them to perform their work in parallel to the installation team. The tool owner emphasized his presence and availability on site and his commitment to respond in real time to any constraint that may arise during the work (contrary to traditional RFI processes that may be untimely, sequential and cause work stoppages).

Principle 4 - "Resolve constraints": This principle integrates with the look-ahead plan and the make ready process in LPS. The P-Sub explained that traditionally each trade was required to provide its own working platform, that not only did not fit the needs of the other trades, but in most cases blocked their access. To resolve this constraint, the trades planned an integrative working platform, that would fit the needs of all trades and would enable them to work in parallel. As described regarding principle 3, the PM and the tool owner had substantial influence to resolve constraints in real time. This included providing design solutions at the Gemba, without triggering a cumbersome system of "design changes".

Principle 5 - "Restructure Resources": the preliminary plan clearly shows that the electrical works were on the critical path, and the electrical team was working at its full capacity, indicating the presence of a bottleneck. It was suggested to restructure the resources within the electrical team. The senior electrical team that worked on the project received a broader role, including mentoring of junior teams in a portfolio of projects, and a reinforced motivated junior team was assigned to the project enabling reduction of the bottleneck effect.

Principle 5 was also implemented by maximizing the potential for off-site pre-fabrications of the piping works, enabling dramatic reduction of the welding required on site. As a result, the piping trade was able to carry out more tasks in parallel, with improved safety and reduced disruptions to the other teams.

Principle 6 - "Control Project Start": In the pre-OCF environment, in general, tool owners would drive the system based on push strategy, meaning that projects would start as soon as possible, regardless of projects maturity levels, and even if the tool vendors' delivery dates were far off. In that situation, the project technically could not be completed, increasing the cycle times dramatically. Under OCF strategy, the tool owner shifted to a pull strategy that triggered the project only once it reached a suitable maturity level, and Just in Time regarding the vendor's delivery date. The tool owner explained that without this principle, "we may end up in situations where after installations are started, the trades can't complete their job and switch to start another installation, then when the prerequisites are met, the trades or the vendor are no longer available, and so on". Thus, the tool owner made sure to complete all prerequisites before the project was launched.

Principle 7 – "Ensure Project Flow": This principle refers mainly to the construction phase once the project is carried out. To ensure project flow, the entire supply chain must align with the project and provide full backup. This was achieved through the personal involvement of stakeholders, with direct communication to coordinate and resolve any issues that arose. The project was carried out with the "…touch the project once…" concept in mind of all trades, while fully focusing on the project, and without diverting attention to future or parallel projects.

DISCUSSION AND CONCLUSIONS

The case study demonstrates application of OCF at the single project level, detailing how it works through implementation of seven principles. The results reinforce the conclusions from empirical results that showed enhanced performance in over 1700 projects where OCF was applied.

Analysis of construction plans in the case study (Figures 8 and 9) revealed over 50% waste removal, in the form of inflated durations that were considered a cushion to absorb delays. We suggest that the presence of non-value adding times in such work scopes reflect planning failure, which leads to inflated internal buffers. It is likely that these types of waste can be found in many construction projects, even when planning is done using proven methods (e.g. LPS), as plans are ultimately based on motivations, constraints, and internal buffers of each individual trade. Thus, setting strategic and tactical goals to reduce durations, may initiate identification and removal of this type of waste. As detailed in the case study, work plans were coordinated on a half-day level of precision, with tight collaboration of the trades, to ensure optimal workflow and waste removal.

Critical production thinking manifests in OCF strategy through the first two principles: "Plan and Integrate Strategically" and "Plan Tactical Targets". These principles are the pillars of OCF and are a necessary condition to OCF strategy success. Once the first two pillars are set and an organization aims to double its throughput, the other principles of OCF should pave the way to the desired results. As presented in the literature review, the principles are deeply rooted in previous LC work, and thus enhance implementation of other methods as well (e.g. LPS).

The interviews highlighted the importance of vertical integration of all parties in the project. This was reflected as senior managers were present in the Gemba, emphasizing their personal commitment, and providing real-time solutions to remove constraints. This integration was reinforced once the WIP levels were controlled, allowing the focus required on the individual project.

The multi-project environment was recognized as a catalyzer for OCF. The trades adopted a macro perspective that enabled them to level the WIP and reduce the CT, and to enable continuous flow from one project to the other. This was also reflected by the relinquishment of the traditional reward mechanisms (e.g. accelerations), preferring stable cash flow, that allows investment in long term resources and human capital fed with continuous work (as reflected from the OCF batching strategy presented in Figures 2 and 3). We argue that a multi-project environment is not a "given condition", but rather a perspective that arises from critical production thinking, and a clear product and value proposition. Therefore, it may apply to a variety of construction environments. For example, a residential building can be examined as a multi-project environment, with each apartment being a sub-project with a different customer (Sacks & Goldin, 2007). Thus, reduction of CT and increasing TH will reflect completed apartments delivered to customers.

This study was limited to the context of OCF implementation on an installation project in a manufacturing plant environment. Further studies are required to test and evaluate the working mechanisms of OCF outside the factory walls and on non-repetitive projects.

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