Chapter 4

A Framework for Using Dynamic Modeling to Support Lean Sustainment in a Complex Setting:

Illustrated With a Case Study From Manufacturing

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ABSTRACT

This chapter proposes a framework for integrating lean and systems thinking tools to explore the dynamics of lean implementations in manufacturing. The value of this integrated approach is in supplementing the operational level principles of lean with the strategic outlook of systems thinking to mitigate adverse impacts of operational complexity on system performance. In particular, the focus of the framework is to enable the sustainment of lean gains in the long-term, a major challenge in manufacturing settings. The application of the framework is illustrated with a case study of a lean implementation for reducing work-in-process (WIP) at a clothing manufacturer dealing with a number of operational complexities such as demand uncertainty, a high product mix and inefficient processes. The case study highlights the usefulness of system dynamics modeling in revealing counterintuitive system behaviors that could compromise the success of the lean initiative. The simulation results demonstrate the application of the framework for sustaining lean implementations in practice.

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INTRODUCTION

Manufacturing systems are inherently complex, meaning they are typically large-scale, interconnected (with feedback connections between different parts of the system or with external sources), and where human agency is strong and conditions are dynamic (sometimes changing rapidly) (Bar-Yam, 1997). The manufacturing environment is also rife with coordination and communication challenges, which are affected by operational complexity and in turn contribute to increasing it, whether due to lack of information (uncertainty), conflicting information (equivocality), or delays and breakdowns in communication. This is why a multitude of process improvement approaches are available and always needed to tackle the countless adverse impacts of complexity in manufacturing. Some are focused on particular outcomes such as total quality management (TQM), while others are meant to be more cross-cutting, such as process reengineering. But perhaps the one that is most encompassing and that has withstood the test of time since its inception in Toyota's production system is the lean approach.

Lean manufacturing is a proven set of tools and techniques for improving an entire production operation from material sourcing to customer delivery. Lean is focused on minimizing wastes in production time, cost, effort and resources in order to maximize overall system performance, such as production throughput and product quality. However, lean is not just a shop floor practice, but also a philosophy of disciplined and continuous improvement, sometimes referred to as "lean thinking" (J. P. Womack & Jones, 2010), which goes beyond the mere tools and techniques for improving a set of processes. Lean thinking is a comprehensive system of beliefs that advocates a change in mindsets about how we perceive work and value beyond our own silos; it redefines value to be always aligned with customer needs; and, it aims to evolve the traditionally disconnected factory towards an integrated enterprise from supplier to customer (Nightingale & Srinivasan, 2011), where workers are empowered and inherently incentivized to create value for the customer. In principle, this is supposed to ensure a sustainable enterprise that can continuously innovate to meet customer needs, while maintaining its own efficiency and effectiveness. However, in practice lean gains are hard to sustain due to emergent behaviors resulting from complexity, which calls for complementary approaches to lean (Haddad & Otayek, 2019).

Systems thinking is such an approach for holistic problem solving in the context of complex systems, with a comprehensive set of principles and tools to that end. The core philosophy of systems thinking is based on exploring the interactions between a problem and all affected parts of the system it's embedded in to find globally optimal solutions instead of a limited local fix (Sterman, 2000). This makes it particularly appropriate for tackling the types of problems encountered in manufacturing, especially those that require a big picture view of the problem before getting to its root cause, or understanding the long-term consequences of proposed solutions. The main qualitative tools of systems thinking are causal loop diagrams (CLD) which enable the elicitation of key variables constituting a system, and the cause-effect relationships between them that govern system behavior. The quantitative arm of systems thinking is system dynamics (SD) modeling which is used to describe the structure of a complex system with mathematical equations in order to simulate its behavior over time (Azar, 2012). These tools have proven useful for tackling 'messy' situations such as recurring problems, or those that have been made worse by quick attempts at fixing them, both of which are common in manufacturing.

Therefore, and in contrast with the reductionist approach to problem solving, both lean thinking and systems thinking have similar underpinning philosophies that advocate for comprehensive and holistic approaches from different perspectives. However, they are not interchangeable approaches but rather complementary. Lean is the vehicle for thoughtful intervention with practical tools, while systems sci-

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