A COMPLEMENTARIST APPROACH TO LEAN SYSTEMS MANAGEMENT

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ABSTRACT

Effective systems management is a desirable, but often lacking, individual and organizational behaviour. An effective management system informs decision making for human, information, technology and machine processes, thus requiring a systemic approach. The consequences for a lack of systems competency are considerable in costs, delays, failures, etc. In this paper, the authors present a complementarist lean systems management approach. As a knowledge engineering approach, it combines the CX tool, Transition-Phase Management model (TPM) and Cascading Failure Model (CFM) methodologies into a meta-methodology to manage lean systems. The CX tool is a system model of both current and desired future states in an organization that aspires to be lean. Based on the Plan-Do-Check-Adjust organizational learning loop, the CX tool provides a means to analyse any current or new system, process or project. The "C" stands for congruence or "equal state" and "X" for all the possible combinations in which the congruence can be developed or improved. TPM provides a mean to manage process change processes; while CFM allows identifying robust process networks. Together they quantify specific gaps to inform continuous improvement. The meta-methodology proposed is a pluralistic approach that integrates all phases of process improvement: diagnosis, solution design, implementation and control while combining social sciences, engineering management and systems engineering disciplines.

Keywords: Lean management systems, CX tool, transition-phase management, resilient systems, knowledge engineering, cascading failure model

INTRODUCTION

The design and use of lean management systems can be a fuzzy and complex process that is assisted by enhanced paradigms and improved processes of how work gets done. Without an internal lean team, assistance by external consultants or by trained internal champions, organizations that want to design their own lean manufacturing system must discern their own implementation paths. This is a difficult task as initiating work and runs the risk of incomplete implementations by omitting required tools or principles Knowledge engineering proposes determining and recognizing patterns and then using those patterns as guidance for system management. However, it is often to "see" and "test" patterns in systems due to complex adaptivity and emergence. Unless or until a system is in a stable state, then knowledge engineering needs to rely on other methods to manage. In some cases, a stable system may not be a healthy system as it is known that disruptors may create change and innovation, which will lead to health. So managing via stable system patterns may, in fact, be the antithesis of continuous improvement, PDCA. Therefore, it is important to first ascertain what the current state of the system is; to contrast that with a desired future state, to identify specific points of insufficiency or instability, and then to manage the transition from current to future state. In this case, specific data points that provide an analysis of system shortfalls, recommendations for improvement and management through the change process as emergence is occurring is a proposed meta-methodology. The methodology will also highlight if and when a system is stabilizing around desired benchmarks and resiliency. It is at that point when knowledge engineering is most useful for ascertaining positive patterns of system dynamics and optimization.

The proposed meta-methodology in this paper integrates all phases of process improvement as an interdisciplinary endeavour: diagnosis, solution design, implementation and control that combines perspectives from the social sciences, engineering management and systems engineering disciplines. This meta-methodology is a pluralist approach to assist stakeholders in determining organizational goals, managing process transition-phases and design in contingency plans based on their own system's resiliency. In other words, what is presented here is a description of an encompassing recommender system, one that improves with the application of continuous improvement.

Problem Context Defined

Lean manufacturing systems are complex systems, with complex problem contexts, that are often addressed with the use of varied lean practices such as just-in-time, value stream mapping, setup time reduction, A3 forms, etc. Lean manufacturing practices, although quite widespread in their use, at times fail to produce the expected results mainly due to a misalignment between the needs of the organization and the tool(s)/practice(s) selected (Doolen & Hacker, 2005). This misalignment produces a state of lack of systems competency, or ignorance, as defined by Felder and Collopy (2012). Systems competency is isomorphic with Flood and Jackson's system of systems methodology (SOSM) (Flood & Jackson, 1991); that is, systems competency arises if a particular tool is applied in the right problem context. Furthermore, systems competency is an emergent property that arises from the interactions of actions, processes and tools implemented, as a result of a systems intervention, in alignment with each other and their problem context.

The problem contexts the authors are interested spans the unitary-simple, unitary-complex and pluralist-simple quadrants from the SOSM. Thus, the main concerns are contexts that fall within the functionalist and interpretive sociological paradigms.

PROPOSED METHODOLOGY COMPONENTS

CX Tool

The CX tool is based on the flow of continuous improvement activity, Plan-Do-Check-Adjust (PDCA), as moving between organizational “thinking” and “doing.” The commitment to PDCA as cultural affair has been identified as a benchmark practice (Womack, Jones, & Roos, 1988). ‘Thinking” or organizational intelligence is enacted during the “Plan” and “Check” phases of the cycle. “Doing” or performance management is enacted during the “Do” and “Adjust” phases of the cycle (Argyris & Schon, 1974). Organizations will blunder when there is a break in the continuous improvement cycle of PDCA (Deming, 1991). For example, if “doing” or performance management is dominant, then work will focus on meeting production quotas or changing job duties to hit metrics. Over time, the culture gets sets toward “doing” as the frequent and valued activity of employees. This phenomenon is common in just-in-time or high volume production settings. On the other hand, if “thinking” or organizational intelligence is dominant, then work will focus on process design or assessing performance and how it occurs. Over time, the culture gets set toward “thinking” as the frequent and valued activity of employees. This phenomenon is common in bureaucratic low to moderate volume settings.

The CX tool is designed to bring a systemized method of creating equal focus on the spheres of performance management and organizational intelligence, the essence of PDCA. It offers a platform to increase awareness about a management system by measuring the state of congruence between, within and among organizational intelligence and performance management elements of the system. The three elements that help measure the sphere of organizational intelligence are: essential ideas, essential processes, protocols, structures and essential deliverables. The three elements that help measure the sphere of performance management are: essential actions, essential standards and essential deliverables. Because of complex adaptivity, the six element do influence each other, creating paired and tripled interactions between them. For each element, actions can be determined by the analyst and then scored in accordance to selected measures of shared performance, such as efficiency, effectiveness, relevance. Based on the state of the six system elements against valued metrics, their interrelationships with each other, a level of congruency is determined. Contrasts of the current state with the future state are an important aspect of understanding a system’s state of congruence ensure that continuous improvement ensues with organzinational intelligence and performance management. This informs the state of lean management system and highlights actionable points of improvement.

Table 1. CX Spheres and Elements

ORGANIZATIONAL INTELLIGENCE	PERFORMANCE MANAGEMENT
Essential Ideas	Essential Actions
Essential Processes, Protocols, Structures	Essential Standards
Essential Assessments	Essential Deliverables

Transition-Phase Management Model

TPM offers a model to anticipate the effects that organizational systems will have on the implementation of a new process and therefore plan how to manage a transition-phase between two processes. TPM is a complementarist approach itself, as it combines systems dynamics modelling with learning curve theory in the form of Levy's (1965) adaptation function theory. Thus, TPM is the result of combining a unitary-simple methodology with a unitary-complex methodology to provide a solution to a problem that portrays both unitary-simple and unitary-complex characteristics.

TPM replicates the behaviour over time of a learning organization while transitioning between two processes, based on an assessment of key organizational variables. TPM's behaviour over time is generated as specified in Equation 1 (Calvo-Amodio, J., Patterson, P.E., Smith, M.L., & Burns, J., 2014)

$$Q_t(t) = \int_0^t [F(s) - a(s) - \mu(s)]ds + Q_0 \quad (1)$$

where

Q_t = percentage of errors per day
Q_0=Percentage of Errors per Day as a result of initial training
a = initial efficiency of the process = *f(organizational culture, training. time)*
μ = process rate of adaptation= *f(experience, learning ability, feedback, time)*
F = Damping Factors = *f(a, μ, forgetting)*

and

$$P = \int_0^t B(s)\, ds + P_0; where$$

$$P_0 = \text{intial desired percentage of errors}$$

$$B = \text{Pressure to Adjust P} = f(|P - Q_t|, time)\begin{cases} 0\ if\ |P - Q_t| \to 0, regardless\ of\ t \\ \geq 0\ if\ \ |P - Q_t| > 0\ and\ (t_f - t) \to 0 \end{cases}$$

Even though TPM was developed under a Healthcare environment, it can be applied to diverse environments so long their problem contexts are similar, as is the case with systemic methodologies. The variables suggested for initial efficiency of the process, process rate of adaptation and damping factors can change depending of the environment. Thus, it is possible to use elements from the CX Tool spheres and the activities identified so long they align with a, μ and F.

Cascading Failures Model

Any complex system, such as a lean management system, will function throughout the interaction of many activities (purposeful activities). Yet, if one or more activities are not performed resilient design to prevent cascading failures. This work focuses on producing synthetic network that models real-world system design to understand cascading failures. The network is modelled as a connected graph *G = (V, E)* which is a collection of vertices ***V*** (also called nodes) with edges ***E*** between them. In this context, elements of the networked system are modelled as nodes of the graph and the congruence measures between these elements are the graph edges. These graph representations are then is used as a tool to convert the network into an adjacency matrix of nodes (components) and edge connections. Assuming ***A*** signifies the adjacency matrix of an networked system under study with ***n*** components, ***A*** is defined as follows:

$$A_{ij} = \begin{Bmatrix} 1\ \forall[(i,j)|(i \neq j)\ and\ (i,j) \in \Delta] \\ 0 \qquad\qquad\qquad\qquad Otherwise \end{Bmatrix} \tag{2}$$

where Δ symbolizes the set of elements. ***A*** is a square symmetric matrix with diagonal entries of zero. A topologically defined graph has elements which are connected based upon the congruence metric. In addition, a degree matrix called ***D*** is used to define the number of connections associated with a specific node or element, and is defined based on the following:

$$D_{ij} = \begin{Bmatrix} d_i & degree\ of\ component\ i\ when\ i = j \\ 0 & Otherwise \end{Bmatrix} \tag{3}$$

The Laplacian matrix is defined as $L = D - A$.

$$L_{ij} = \begin{Bmatrix} d_i & i = j \\ -1 & when\ i \neq j\ and\ i\ is\ adjacent\ to\ j \\ 0 & Otherwise \end{Bmatrix} \tag{4}$$

In reviewing the literature in algebraic graph theory (Fax & Murray, 2004; Jamakovic & Uhlig, 2007; Wu, Barahona, Tan, & Deng, 2011) in systems and controls, the second smallest eigenvalue of the Laplacian matrix has appeared as a critical parameter to quantify the *resilience properties* of dynamic systems that operate over network. The second smallest eigenvalue of a Laplacian matrix is known as the *algebraic connectivity*. The algebraic connectivity describes the average difficulty to isolate an individual node (component) from the rest of the system (Fig. 1). Therefore, a network has a more robust state if the algebraic connectivity of the network is maximized (Wang & Chen, 2002a, 2002b).

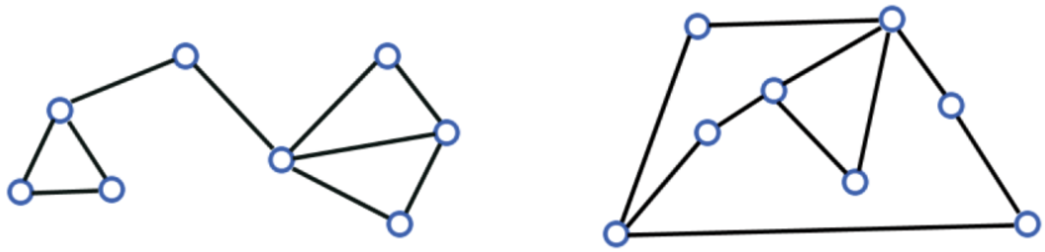

Figure 1: Even though both graphs have the same degree sequence, the graph on the left is considered weakly connected. On the left the algebraic connectivity equals 0.238 and on the right 0.925

The following constraints are defined while modelling the networked system:
1. A component is not connected to itself, meaning that the diagonal of the adjacency matrix is a diagonal of zeroes.
2. A system is represented as a connected system; therefore there are no isolated components (or sets of components) with no connections to any other components.

With a network model available, one can investigate how to improve the resilience of the system by systematically improving the congruence metric of the given edges. Optimization methods can be used to optimally allocate resources to improve those edges (i.e. congruence metrics) which most improve the resiliency of the network.

THEORETICAL MODEL

Even though the CX Tool, TPM and CFM tools were developed with diversified purposes in mind, together it is posited that they can provide an iterative and systemically quality assured platform to enhance lean management systems design, deployment, testing and data driven change navigating through realignment of the organizational culture and context through progression to higher degrees of system congruency and better PDCA cycles.

- The CX tool is an interpretive methodology that allows the system analyst to identify and measure qualitative aspects of the lean management system against valued metrics of performance.
- TPM is a functionalist methodology that provides managers of complex systems a means to deploy the transition-phase between processes
- CFM is a functionalist tool that can detect failures in a complex system. It is to be used to check hubs and links in the networks within a system as a systemized quality assurance approach.

The proposed methodology has three phases that can be used in a linear or in a non-linear fashion. If used in a linear fashion, Figure 1 presents the proposed order:

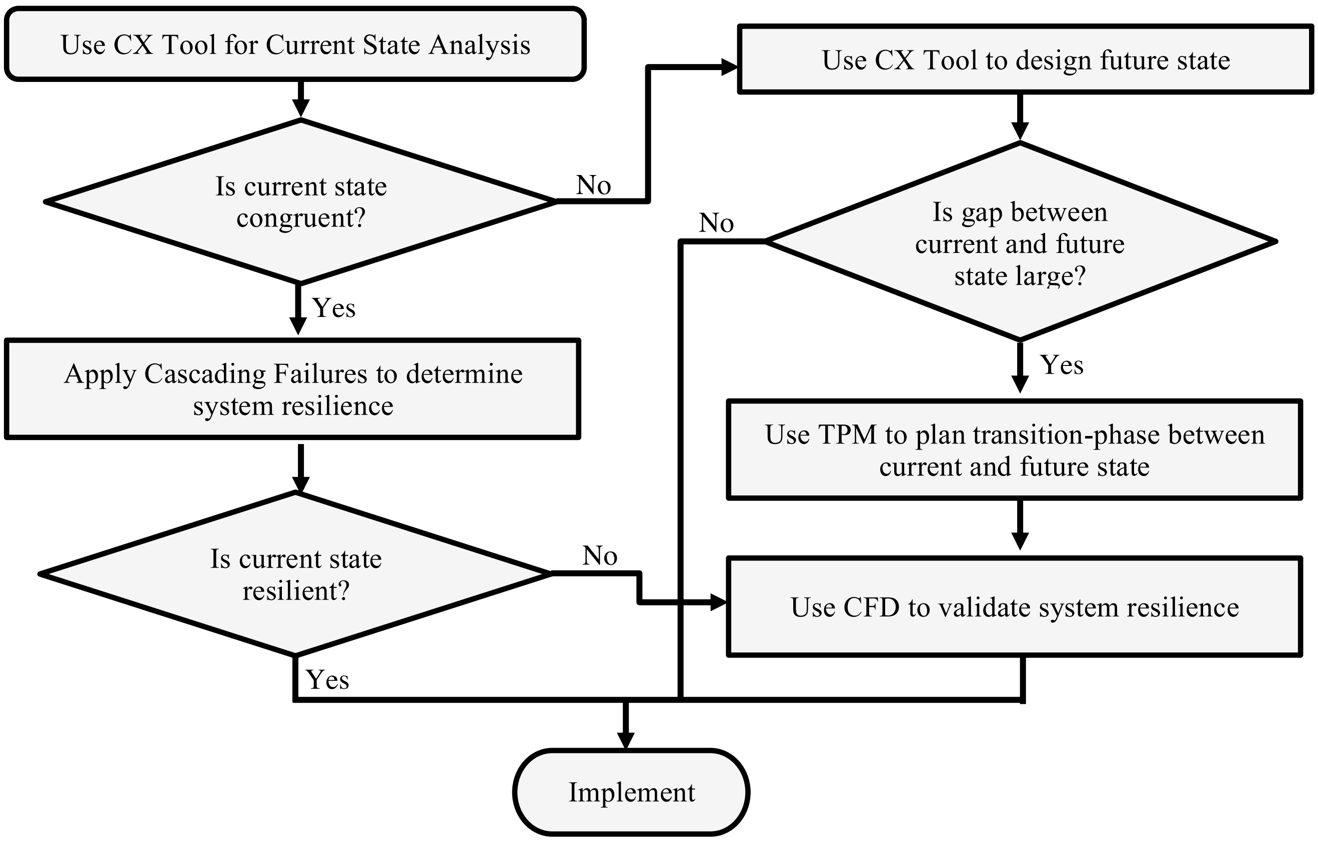

Figure 1. Proposed Design Methodology for Lean Manufacturing Systems

The non-linear nature of the Design Methodology for Lean Systems Management is depicted in Figure 2.

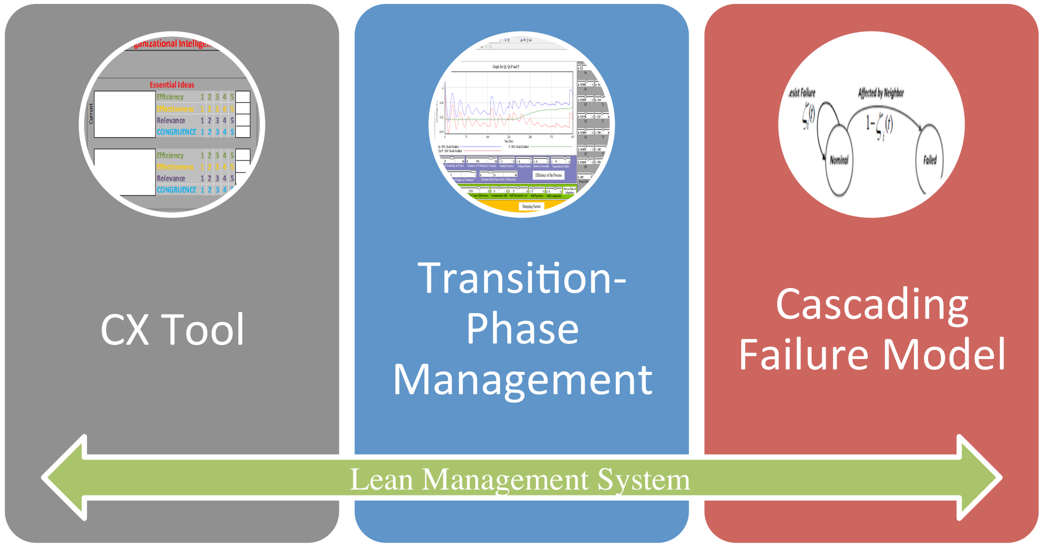

Figure 2. Lean Management System

CONCLUSIONS AND FUTURE WORK

This paper set out the theoretical and explanatory constructs of the meta-methodology for an inductive synthesis of complex organizational human and information systems. The potential for a integrated, iterative and automated approach to PDCA to wage against system dysfunction and/or failure provides the impetus for further development.

Theoretical, empirical and scientific studies have taken place for each component of the meta-methodology, the CX Tool, TPM and CFM. However, it is now of interest to integrate these methodologies to better foster system resiliency. Current studies are underway to automate the use of the CX Tool and TPM through CFM and artificial intelligence approaches. Through spreadsheet analysis, it is hoped that it will be possible to test this meta-methodology in various types of cultures and contexts to maintain system health and to mitigate against risk of failure. As a toolkit for lean performance management, this toolkit requires both fidelity and validity testing.

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