Modeling and Simulation to Assess the Role of Culture for Successful Lean Transformations

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Abstract. Lean manufacturing has been embraced by many companies as the business model to promote operational excellence. However, a high percentage of lean implementation attempts have failed. This failure is often attributed to the sole focus on the hard side (tools) of lean, at the expense of the soft side (culture). Most of the research investigating the culture-related aspects of lean either attempt to raise awareness about culture or merely promote a conceptual approach. This paper proposes a simulation-based method that can be used to identify and assess the role of various factors essential to forming an organizational culture conducive to successful lean transformations. The culture of an organization emerges from interaction among members, interaction with the environment, and personal attributes. Agent-based modeling is an effective technique for evaluating dynamic systems of interacting agents and therefore is potent for modeling complexities that arise from interactions of the system components. However, due to blurred indicators which exist in defining culture, many measures are described subjectively by linguistic terms. Therefore, the use of fuzzy logic is proposed to emulate subjective human decision making by team members during interactions. Preliminary efforts for fuzzy-integrated, agent-based modeling and simulation are presented in an attempt to demonstrate the potential of using the method to identify and assess factors influencing organizational culture for lean transformations.

Keywords: Lean · Culture · Agent-based modeling and simulation · Fuzzy logic

1 Introduction

Over the years, many organizations have invested in attempts the successful adoption of lean practices. It is estimated that roughly 98% of lean implementation attempts fail [1]. Hence, the enthusiasm of adopting lean as a strategy for organizational transformation has somewhat waned [2]. An extensive review published in 2018 [3] illustrates the evolution of lean implementation. As reported, the emphasis was initially on understanding the current state of lean implementation, developing process improvement practices, and implementation in manufacturing industries, with particular focus on lean in services sectors. The study, as well as subsequent research, highlighted issues with sustaining successful lean transformations, noting that the failures were due to the conventional approach of focusing only on lean tools. The importance of the relationship between

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competitive skills, the impact of employee participation, and the expected effects of soft practices on successful lean transformations are acknowledged in later studies [4].

However, one aspect that has not received sufficient attention is related to organizational culture. Although implicitly stated in many studies, few have explicitly incorporated organizational culture in the analysis of lean transformations [5]. Moreover, the desired culture for successfully sustaining lean implementations is not adequately defined. Most studies either merely acknowledge culture as a crucial factor, or simply provide a conceptual work [6, 7]. Therefore, examining the relationship between factors influencing organizational culture and sustaining the improvements may lead to success with lean implementations.

The study of organizational culture involves investigating how information is shared among members, and how this affects their behavior and interactions. Agent-based Modeling (ABM) is a technique that represents a given system as a collection of individuals displaying certain behaviors, to analyze how the interaction of these individuals produce the phenomenon [9]. ABM captures the collective and emergent behavior of agents in a complex system which is difficult to analyze using other methods such as analytical modeling [10]; however, it is an effective tool because simulating human behavior involves many factors and interactions, which can be integrated within ABM [11]. ABM also facilitates the integration of results from previous studies and many partial theories related to a phenomenon [12]. Each of these factors make ABM valid method to study the factors affecting organizational culture and their role in lean transformations.

Another important aspect to consider when modeling human behavior is the uncertainty involved. Unlike mechanical systems, human performance fluctuates based not only on their ability, training and education, but also on psychological states and traits [13]. Furthermore, humans are not confined to acting in accordance with predetermined rules or local patterns [14]. One approach to integrate such subjective uncertainties involved with human behavior is through the integration of fuzzy theory. In fuzzy-integrated ABM, agents make decisions based on fuzzy logic rules; this prevents over-simplification of agents, by taking into account the stochastic aspects of human behavior [14].

In this paper a fuzzy-integrated ABM approach is proposed to explore the relationship between organizational culture and sustaining lean transformations. The rest of the paper is organized as follows: Section 2 presents the theoretical framework foundational for this study as well as the methodology for fuzzy-integrated ABM development. An example application of the approach is presented in Sect. 3. Concluding remarks and future work are covered in Sect. 4.

2 Research Methodology

This section presents the theoretical framework formulated to propose an approach for developing the organizational culture for successful lean transformations, and the fuzzy-integrated ABM to study the behavior posited therein.

2.1 Theoretical Framework

Schein [15] defines culture as a set of practices accepted and adopted by a group of people. He also posits that the creation of culture evolves through three levels: (a) values that get embedded in (b) practices and observable behaviors that eventually become (c) basic assumptions of a culture that are again reinforced by being reflected in (b). The creation, evolution and sustainment of a new organizational culture requires that members interact among themselves and exchange their beliefs, norms and values. We study the practices in the Toyota Production System (TPS) to examine and reflect the evolution of the three levels of culture presented by Schein [15]. In TPS, the Hoshin Kanri process is where the leadership engages in strategic planning and goal alignment. This process helps translate and convey the organizational values into actionable goals. Which are then reflected in practices and behaviors. Managers plan for achieving those objectives via Jishuken, or management-driven kaizen. Ultimately, the improvements towards the goals are implemented in the floor through the team members (TMs) who engage in Kaizen activities. This series of processes observed within the TPS, and its mapping to Schein's three levels for organizational culture development, are shown in Fig. 1.

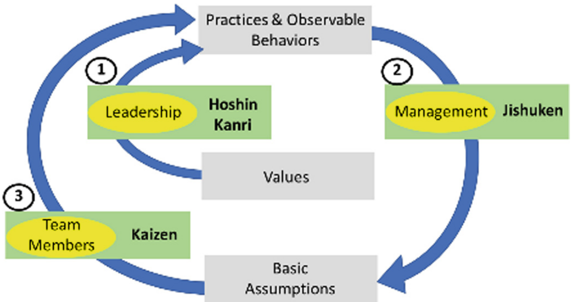

Fig. 1. Mapping of TPS practices with Schein's model

Thus, for effective transformation of an organization's culture, merely engaging in Kaizen activities—the widespread practice in companies for lean implementation—is not sufficient. As illustrated in Fig. 1, the transformation must be initiated by the leadership setting new values and management engaging in goal alignment; the latter must work with TMs tasked with implementing the changes, ultimately leading to the adoption and sustainment of new values. Space limitations in this paper do not permit a comprehensive discussion of the framework for lean organizational culture transformation illustrated above by integrating TPS practices and classical organizational culture theory. More details about this model are presented in [16].

Validation of this theoretical framework requires establishing and testing a number of different null hypotheses, which include: 1) An ambiguous problem-solving mechanism benefits organizations adopting new practices (importance of Kaizen), 2) Vague organizational values enable the organization to establish new practices (importance of Hoshin Kanri), and 3) The shorter the time taken for cultural transformation, the stronger the culture is to adapt to the internal and external changes (importance of Jishuken).

2.2 Integrating Fuzzy Logic and Agent-Based Modeling

A fuzzy-integrated ABM approach that can be adopted to study the framework proposed in Sect. 2.1 is presented. While the approach can be customized to assess different hypotheses, the discussion here is limited to model formulation for the first hypothesis. Kaizen happens at the lowest level of an organization where TMs are engaged in improvement activities to develop new practices. To specify interactions between TMs, the team leader (TL) and the work environment (i.e., environment), a collection of agents, and interactions among them, as shown in Fig. 2 are considered in the ABM. The environment is represented by two (auxiliary) agents, (a) task and (b) team architecture, which have task complexity and problem solving method, and organizational structure and decision making mechanism as attributes, respectively. TLs and TMs (physical agents) have the same attributes (see Fig. 2) but can each have different values for them depending on their roles and responsibilities. The performance of the system is determined based on the interactions between the TL, TMs, and the environment. System performance is represented by two (auxiliary) agents: performance effectiveness and task completion (see Fig. 2 for attributes). During the simulation, if the sum of TM agents' attributes is greater than the minimum required to solve the problem (i.e., skills threshold is satisfied), then the problem is recorded as solved by task completion agent and a new task will be assigned. If not, the TM and TL agents continue interacting among themselves (up to a finite amount of time) to develop the requisite skills to solve the problem. At each tick of time the TM and TL agents' attributes are assessed (by the collective team capabilities attribute). If the skills threshold is reached, the task is recorded as complete and a new task is assigned. However, if the allocated time elapses and the skills threshold is not satisfied, then the task is recoded as incomplete (no task success) and a new task is introduced. This process continues for the duration of ABM simulation.

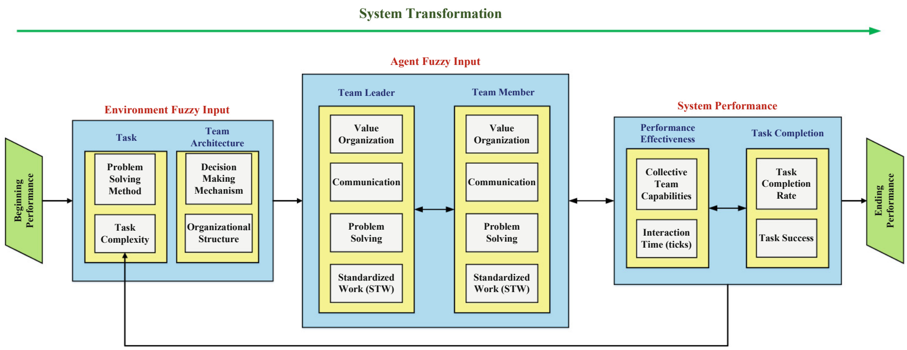

Fig. 2. Fuzzy agent-based connectivity in the overall system

The agent attributes illustrated here are adopted from literature and based on entry-level training requirements observed in the TPS [17]. In the TPS, TM training requires progressively mastering knowledge and skills in four subject areas and are demonstrated by: 1) gaining an understanding of objectives and values of the organization, 2) understanding the concept of standardized work (STW) and its application, 3) gaining structured problem solving capability, and 4) cultivating communication skills [17]. These are the four areas considered to be attributes for agents in the ABM (Fig. 2); the expected progressive maturity of knowledge and skills, illustrated in Fig. 3, are considered to be different levels of the respective attributes for TMs.

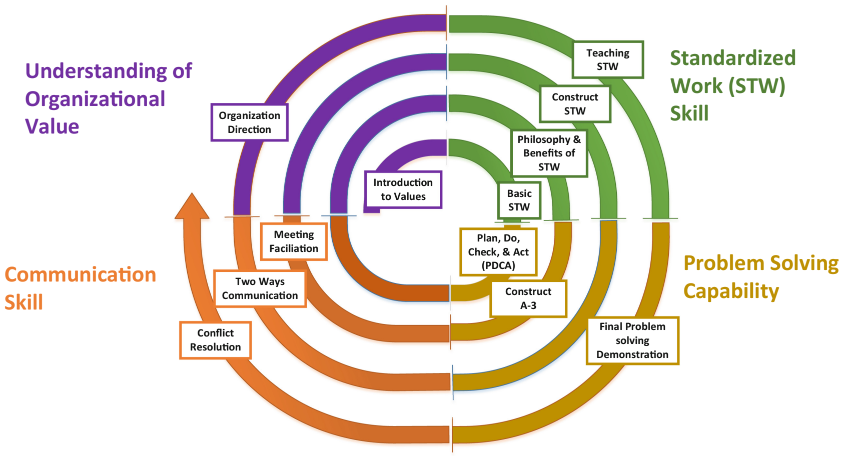

Fig. 3. A framework for employee improvement

In a fuzzy-integrated ABM, the agents are fuzzy agents, while the environmental attributes are also fuzzified. To implement this, the architecture of the ABM for a Kaizen activity is first determined. Then, the attributes of TMs and the environment are defined, and the rules for interaction between agents and the environment and agent decision making rules are established. Fuzzy membership functions for all attributes are defined accordingly and incorporated in ABM to develop the fuzzy-integrated ABM. The inputs to the model are the attribute values for the environment, TMs, and TL agents. The output is the improvement of TM attributes and their ability to complete a given task.

3 Example Application of Fuzzy-Integrated ABM

This section presents an example application for the preliminary demonstration of the proposed approach. A real-world industrial organization that is early in its lean journey is used as the basis to determine the agent attribute values. For the testing, each attribute of the TM and environment agents are fuzzified by using a triangular-shaped membership function. For the TM attributes of understanding the organizational value, communication skill, problem solving capability, and standardized work skill, four fuzzy sets were defined. The range of these fuzzy sets correspond to levels shown in Fig. 3. Figure 4 illustrates fuzzy membership functions developed for communication and standardized work skill attributes, based on the respective fuzzy sets.

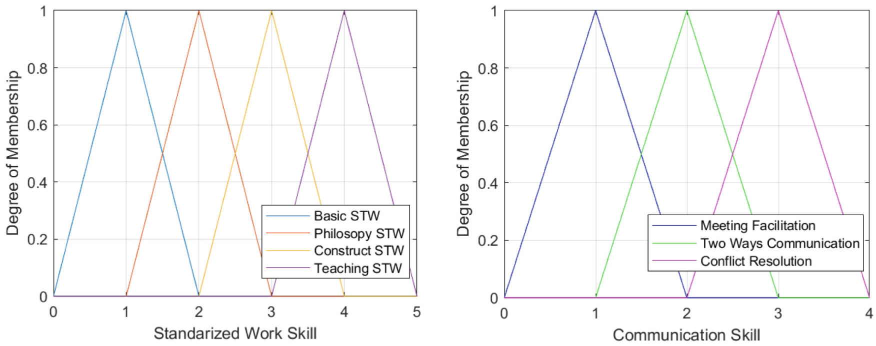

Fig. 4. Fuzzy set values for standardized work skill and communication skill

Problem Solving Method	Task Complexity	Decision Making Mechanism	Organizational Structure
Extent of structured problem solving methodology in place	Simple	Collective	Networking
	Moderate	Centralized	Hub & Spoke

Fig. 5. Different levels of environment agent attributes

A different levels of environment agent attributes (range 0 to 4) is shown in Fig. 5. The subjective nature of agent's attributes and environment attributes make it impossible to assign a crisp value (e.g., a percentage value for communication skill is not logical). The same also applies to the behavioral rules (i.e. TM's improvement process). Therefore, the fuzzy techniques must be incorporated into the ABM to fuzzify subjective factors that cannot be assigned a numerical value. Figure 6 is an example of a rule expressed in natural language to achieve this.

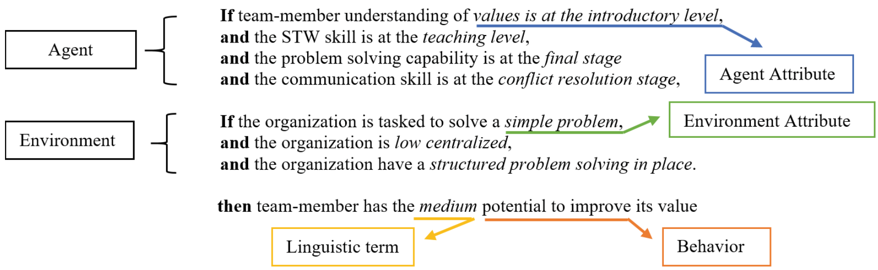

Fig. 6. Example protocol expressed in subjective, natural language

For this simulation a hub & spoke organization was assumed, i.e., TMs only interact with TL (not among them) to complete their task. Moreover, it was assumed that there is a structured problem solving methodology in place. The effect of three different attributes were tested, each at two different levels, giving rise to eight scenarios (Fig. 7).

The results for the eight scenarios, comparing two TMs' improvement of understanding of organizational objectives and values, are illustrated in Fig. 8.

Decision Making Mechanism	Types of TL	Types of TM
Centralized	Average Understanding of Organization Value (UOV)	Low UOV
Decentralized	High UOV	Med-Low UOV

Fig. 7. Attributes under study

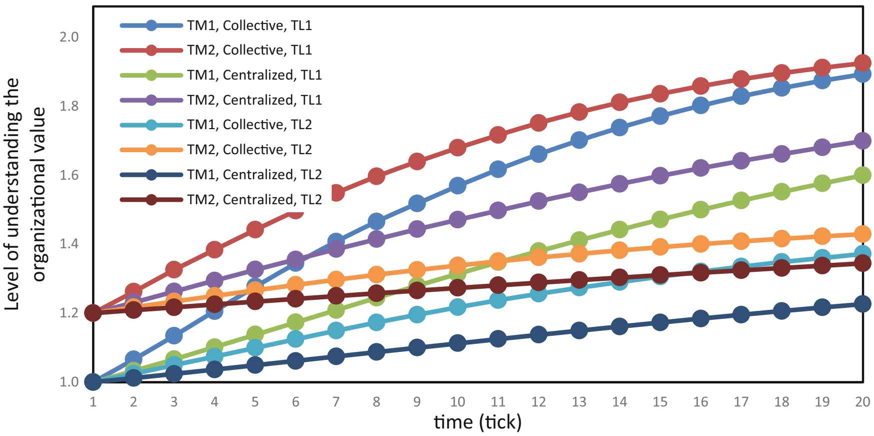

Fig. 8. TMs improvement in UOV with respect to TM, TL, and the environment attributes.

As observed from Fig. 8, the highest improvement in TMs UOV occurs when there are higher levels of understanding of UOV at the management level. It is also observed that TMs initial level of UOV becomes irrelevant as time progress. The importance of collective decision making is also evident. The top two TMs with the highest UOV improvement was observed in scenarios where employees had freedom to express their opinions and make decisions collectively, versus centralized decision making. While the results of the example do not provide any conclusive evidence, it enables verifying that the fuzzy-integrated ABM approach proposed can be a versatile approach to study the factors affecting organizational culture and effective lean transformations.

4 Conclusions and Future Work

The importance of organizational culture to sustain improvements made through lean implementations is widely recognized. Organizational culture, however, is an abstract concept that is difficult to model and analyze. Therefore, limited effort has been dedicated to the in-depth study of the role of culture for lean transformation. Here, a fuzzy-integrated ABM approach is proposed to explore the relationship between organizational culture, its influential factors, and the extent of their impact on establishing new practices to sustain lean transformations. A simplified example is used to demonstrate the potential of using the using fuzzy-integrated ABM to study influential factors. Comprehensive modeling of organizational scenarios that consider all aspects related to TMs, TLs, management/leadership as well as other environmental factors will be conducted in future work to investigate the validity of the theoretical framework and the hypotheses. Such analyses can be useful to better understand what organizational culture-related factors are important to sustain lean transformations.

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