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Abstract

Purpose: Organizations are more dynamic, competitive and uncertain than in the past; therefore, they must be highly flexible in order to provide an agile condition for responsiveness to customer changes. This paper aims to explain how being Agile can improve the Six-Sigma methodology and explore how Agile and Lean Six Sigma (LSS) principles work together. We will outline the benefits of their relation with each other.

Design/Methodologies/Approach: This paper summarizes the previous literature on Agile, LSS, and the intersection of both disciplines, utilizing a subject matter expertise (SME) approach. The perspective of this study is based upon practitioners understanding in various manufacturing environments.

Findings: The paper will present the views on the benefits of using Agile and Lean Six Sigma together, leading to a discussion on how the combination of the disciplines may be taken as a step to further enhance the competitiveness of an organization. The paper will conclude with a model of integration of Agile and Lean Six Sigma, based upon a relationship matrix. The criteria for understanding the relationships will be identified through the literature.

Practical limitations/Implications: Comprehensively reviewing the literature, we extract criteria representing agility of an organization based upon a descriptive study research approach. A new detailed description for integrating Lean Six Sigma and Agile will be proposed.

Originality: Lean Six Sigma has been widely discussed, but there has been limited academic research about the implementation of Agile and Lean Six Sigma. This article contributes through demonstration the value of using Agile Six Sigma together in organizations to be more responsive to uncertainty.

Keywords: Lean Six Sigma, Agile, Operations Research

Introduction

Organizations are more complex and vulnerable than in the past since they are more dynamic, exhibiting both deterministic and stochastic characteristics, and subject to both deterministic and stochastic forces over time; thus, they face more risk for disruption. Whilst the continued search for efficiency improvements is essential in a fiercely competitive marketplace, the challenge is to find ways in which vulnerability can be contained and managed (Christopher & Rutherford, n.d.).

Many scholars have highlighted how the risk of different organizations' disruption has grown and how great the consequences of catastrophes might be (Oke & Gopalakrishnan, 2009). There are many obvious sources of risk external to an organization, e.g. terrorist attacks, floods, earthquakes and the like. It is our contention that a growing source of risk lies within the organization itself and that, once recognized, that risk can be mitigated or even removed. Thus, catastrophes in organizations have renewed interest in the concept of resilience, especially as it relates to complex systems vulnerable to multiple or cascading failures (Park, Seager, Rao, Convertino, & Linkov, 2013). Although the meaning of resilience varies in different contexts, in general, resilience is understood to mean the capacity to adapt to changing conditions without catastrophic loss of form or function (Park et al., 2013).

Resilience is the 'ability of a system to return to its original (or desired state) after being disturbed. (Carvalho & Cruz Machado, n.d.). In other words, the capacity that ensures adverse shocks do not have long lasting adverse development consequences (Smith & Frankenberger, 2018). In the context of business today, a resilient organization must also be adaptable to able to face unpredictable events. Thus, for increasing the resiliency, the organization needs to be agile as well.

Agile methods have been prevailing in software development area over the last few decades, and they have proven to be fruitful for managing and operating software development projects. The Agile method may be used in other projects and industries too.

Agile software development is based on an incremental, iterative approach. Agile methodologies are open to changing requirements over time, instead of in-depth planning at the beginning of the project. These methodologies encourage constant feedback from the end users.

In Agile methodologies, leadership encourages teamwork, accountability, and face-to-face communication. Agile teams usually concentrate on fast and concise improvements in a very short time, usually daily or even hourly. They work on iterations of a product over a period of time.

In addition to being Agile, the organization may use Lean Six Sigma (LSS) principles, since sometimes Agile teams lack a strategic approach to improve the process or solve the problem. LSS is prepared for unknown and unforeseen issues for the team to understand and provides a structured approach for an organization to manage and accept its risks (Arnheiter & Maleyeff, 2005). Employing these techniques gives companies an opportunity to monitor processes in analyzing the organization's efficiency.

By using Six Sigma tools, the organization is assisted in capturing important information and identifying events which may contribute to the failure of specific outcomes. Six Sigma provides a set of tools and guidelines that can be used to identify future known opportunities which could result in failure for a reduction in variation in the system and improve the capability and quality of organizational processes, services, and products. Six Sigma teams apply statistical techniques to measure effectiveness, utilizing a specific approach to solve the existing problems and improve productivity and customer satisfaction. SS is most useful in identifying the deficiencies of quality in services and products. Additionally, a continuous improvement methodology, like LSS, assists leadership in managing both the operation of the organization and the inherent risk associated with it by eliminating waste and inefficiencies.

In this research paper, we will integrate Lean Six Sigma, a statistical and analytical problem-solving approach based on the DMAIC phase structure, with the Agile approach, to make the LSS method even more attractive to different organizations that might not have implemented LSS. In addition, we will bridge the gap between the two approaches and focus on the areas where both can meet and benefit from each other.

What is Agile?

Agile in software engineering is well known and many practice it. Agile is a collection of values and principles that represent a philosophy and a way of thinking about value delivery to customers and achieve better business outcomes (Sohaib, 2010).

Agile is about embracing the uncertainty of change and continuously improving organizational ability to frequently produce high-quality output. The substance of Agile is being flexible and adaptive to maximize the value of the solution that is being produced, and becoming Agile means being open to possibilities and options. Dove (1999) defined Agile as a word that is associated with cats. The author referred to the word “cat” as being Agile because it is both physically adept at movement and mentally adept at choosing useful movement appropriate for the situation. Dove (1999) believes that Agile carries with it the elements of timeliness and grace, purpose and benefit, as well as nimbleness, where speed and urgency are important.

The authors of this paper views agileness and flexibility in organizations as a continuous improvement strategy. Organizations have always had to be sufficiently agile to adjust to their changing environment, or risk ceasing to exist. One of the key differences between traditional project management and the Agile method is the amount of up-front analysis and planning.

Traditional project management calls for comprehensive planning and adherence to the plan; Agile calls for just enough planning and applies analysis, followed by responsiveness to change. The main reason being Agile has been discussed in recent years is that the environment is changing faster than it used to, and faster than most organizations are capable of matching (Fan, Xiao, & Wang, 2014)(Day, 1994). The continuous and unexpected changes may pose an unfamiliar business situation and represent a threat to organizational resilience, because the pace of change is

accelerating and potentially outpacing the organizational capabilities. Thus, continuous improvement efforts need to be coupled with an awareness of the pervasive changes in customer choices and requirements, new product introduction, flexibility, delivery, quality, speed to market, and competitive priorities of responsiveness and wider variations in the business environment.

The authors now prefer to define Agile succinctly as the ability to manage and handle risks effectively. Our intent is to identify the competitive focus that would result from the synergistic effect of Lean Six Sigma and Agile together. *Figure 3* presents the phases in Agile development. The phases should not happen in succession; they are flexible and always evolving, and may happen in parallel.

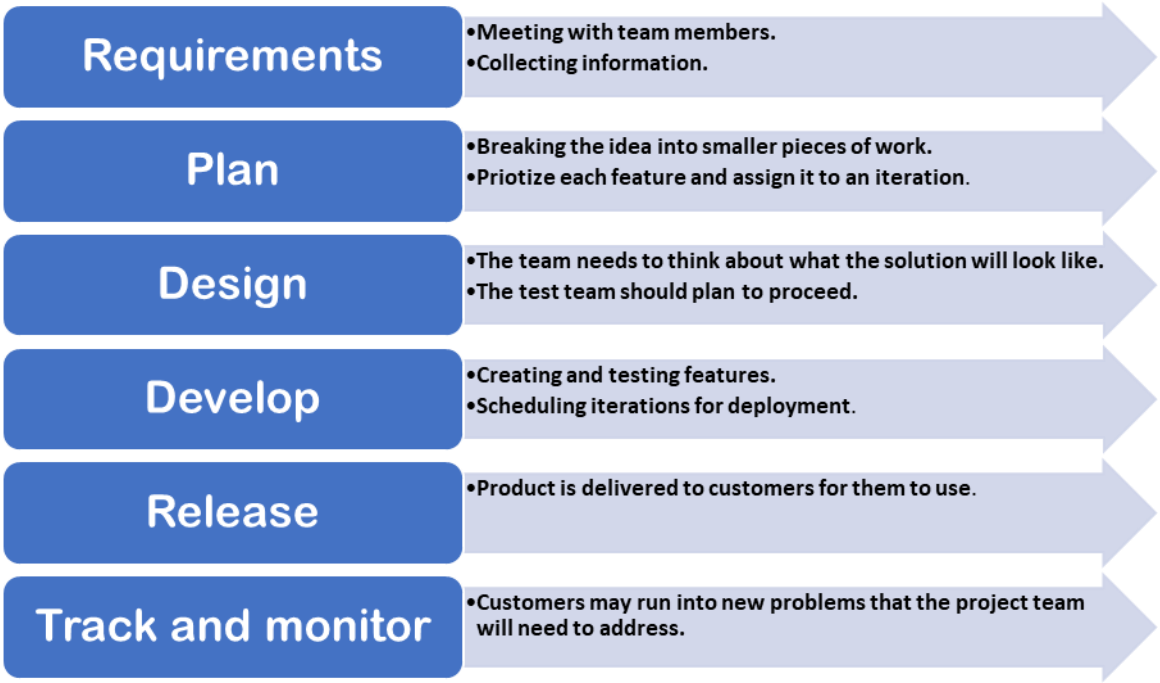

Figure 3: Phases in Agile development (Sharma, Sarkar, & Gupta, n.d.).

What are the Drivers of using Agile?

The main driving force behind being Agile is uncertainty and instability. Although the application of Six Sigma in other sectors is growing, the majority of the publications reviewed discuss the implementation and the problems encountered within the manufacturing sectors (Tjahjono, et al. 2010). As a case of application, the manufacturing industry has tended to gradual updates and adaptations but experiences sudden changes. Manufacturing also needs adjustment and settlement in response to the prevailing market circumstances. The pressure on manufacturing, such as spreading customer choice and expectation, competitive priorities, automation, and price or cost considerations have been dictated by the market.

In order to win business competition for any company, all competitive thrusts should be considered. A prosperous company must develop the ability to explore and achieve the competitive benefit of synergy. To remain competitive, manufacturers should decrease lead times and produce products at lower cost and higher quality. Also, they have to remain proactive and innovative to be sustainable.

Integration of all novel technologies, automated systems, business strategies, experts, scholars, data scientists, and management lies at the foundation of these competitive capability. Successful organizations must be able to forecast, adapt, and respond to sudden changes and risks using tactical initiatives to achieve strategic objectives. It is necessary to engage in creatively initiating change and to become adept in it. Survivors of the current competitive storm are those organizations that use their proficiency in adapting to change as a lever to outperform their competitors.

What is Agile Manufacturing?

Agile Manufacturing is a recently generalized idea that has been thought of as the 21st-century manufacturing model. A group of researchers in Iacocca Institute in Lehigh University (P.T. Kidd, 1996) brought a concept of Agile to manufacturing. There are not many case studies of teams using Agile for things outside of software, but there are a couple examples (Gehani, 1995) (Paul T. Kidd & T., 1994). Agile manufacturing has been defined with respect to the Agile enterprise, products, workforce, capabilities, and the environment that gives impetus to the development of Agile paradigm. The main points of the definitions of various authors may be summarized as follows.

Goldaman et al. (1993) explored the impacts of technological innovations and organizational innovations on the competitiveness of manufacturing enterprises by considering the emergence of the highly-responsive and Agile manufacturing enterprise. They concluded that the key to being Agile in a manufacturing enterprise is a more flexible approach to inter-firm cooperation and the development of the creative skills of the management and the workforce. At the end, Goldaman et al. (1993) found that products and services with high information and value-adding content, being responsive to social and environmental alternations, and being responsive to change and uncertainty play an important role in the Agile concept.

Goldaman et al. (1993) also explained how companies are attempting to be Agile through more efficient manufacturing process development by describing a benchmark study at leading companies in the communications, defense, medical products, and computer industries. Goldaman et al. (1993) believed highly customized, high quality product is one of the main points of Agile.

Burgess (1994) considered the new and evolving concept of Agile manufacturing and its ability to adapt to a major organizational change through a stage model. The author emphasized a synthesis of diverse technologies such as Business Process Redesign (BPR) and Business Network Redesign (BNR).

Gehani (1995) stated Agile is a dynamic concept which has the ability to grow businesses in competitive and unpredictable markets by responding quickly to changes driven by a customer-based valuing services and products.

In terms of outcomes, Yusuf, Sarhadi, & Gunasekaran, (1999) claimed that an Agile organization can quickly satisfy customer orders; it may frequently introduce new products in a timely manner, and can even get in and out of its strategic alliances speedily. However, a further insight into Agile could be gained by looking at the specific and operational issues.

Based on the explorations of Paul T. Kidd & T. (1994), Agile may be defined as the synthesis of a number of enterprises that each have some core skills or capacities which they bring to joint operation, thus enabling the cooperative enterprises to adapt and respond quickly to changing customer requirements. They go on to say that Agile is much more than the speed of doing things and flexibility for a response: being Agile requires a massive structure and infrastructure change because it includes the synthesis of the developed and well-known technologies and methods of manufacturing, such as LSS.

A fairly specific and concise definition of being agile has been proposed by (Kumar, Motwani, & Seidman, n.d.), which is the ability to accelerate the activities on the critical path and time-based competitiveness.

Goldman and Nagel (1993) confirmed that Agile mutually corresponds with Lean Manufacturing, Six Sigma, Computer Integrated Manufacturing (CIM), Total Quality Management (TQM), Employee Empowerment and Optimized Production Technology (OPT). They contended Agile manufacturing reconciles all flexible production technologies, with lessons learned from quality management, Six Sigma and Lean production management.

The Lean Six Sigma methodology

Six Sigma was developed by the Motorola Corporation in 1986 and aims to improve quality by identifying and correcting the causes of variation. The Six Sigma method has two major perspectives: business and statistical. Linderman, Schroeder, Zaheer, & Choo, (2003) discuss the Six-Sigma method from a statistical, probabilistic, and quantitative point of view. From the statistical point of view, the Six Sigma approach attempts to drive unacceptable outcomes to six standard deviations (represented by the Greek letter sigma) from the mean, or 3.4 defects per million opportunities, or a success rate of 99.9997%.

If a process is operating at three sigma from the mean, interpreted as achieving a success rate of 93% or 66,800 defects per million opportunities, that process requires correction. Therefore, the six-sigma method is a very rigorous quality control concept, where many organizations struggle to improve past the three-sigma level. Figure 2 illustrates the difference between two, three, four, five and six Sigma.

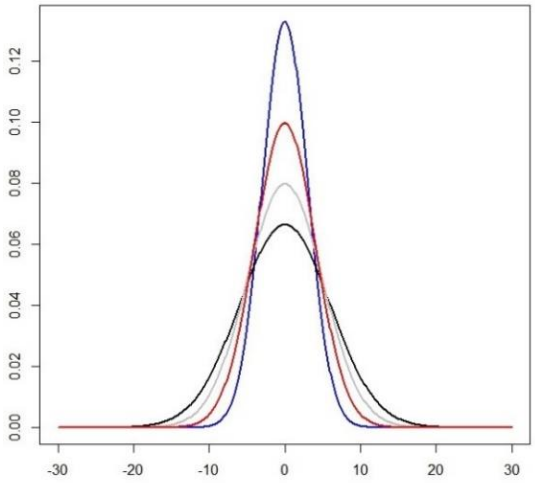

Figure 4: The Difference between Three, Four, Five and Six Sigma.

From the business viewpoint, Six Sigma is defined as a "business strategy used to improve business profitability, to improve the effectiveness and efficiency of all operations to meet or exceed customer's needs and expectations" (Antony & Banuelas, 2002). The Six Sigma approach, first applied in manufacturing operations, rapidly expanded to other functional areas because Six Sigma helps to handle competition, which has increased considerably in today's business world. Particularly, Six Sigma helps because it enables organizations to achieve improved quality and reduced costs, resulting in greater customer satisfaction and loyalty.

Six Sigma brings structure to process improvement by guiding the initiative through a five-stage cycle of define-measure-analyze-improve-control (DMAIC) (Figure 3) (Andersson, Eriksson, & Torstensson, n.d.). Each stage has a number of key processes and techniques, such as to define and measure the process, project boundaries and requirements of the customers, develop a data collection plan, determine and control process variation, and implement the improvements using statistical process control and design of experiments, to name a few.

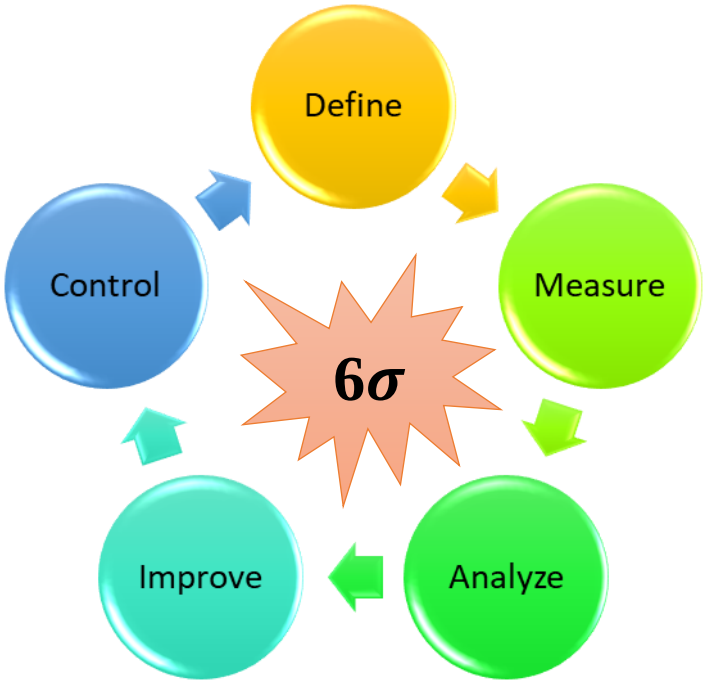

Figure 5: The DMAIC cycle.

In the Toyota Production System, commonly referred to as Lean or Lean Manufacturing, specific types of manufacturing was test hat absorb personnel, resources, or time, but do not add value to the overall process or to the end user of the service or product, are eliminated. Seven wastes have been identified: (1) overproduction, (2) defects, (3) inventory, (4) over processing, (5) transportation, (6) waiting, and (7) motion (Pepper & Spedding, n.d.). Lean is a process that continually decreases these wastes and improves workflow to produce a high-value product or service.

The successful application of Lean and Six Sigma is not limited to manufacturing, having been applied to service industries and governmental operations (Quinn, Lemay, Larsen, & Johnson, n.d.) (Van Der Aalst, Rosa, Flávia, & Santoro, n.d.) (Birchall, Chanaron, Tovstiga, & Hillenbrand, 2011) (George, n.d.). Whereas Lean focuses on reducing process waste, and Six Sigma focuses on reducing process variation, these approaches are often complementary, which has led to merging them into a single strategy, the Lean Six Sigma methodology (Cucoranu, Parwani, & Pantanowitz, 2014).

The relation of Lean Six Sigma and Agile

The relation of Lean Six Sigma and Agile aims to target every type of opportunity for improvement within an organization. Agile complements Lean Six Sigma philosophies by providing responsiveness and adaptableness. Whereas Lean Six Sigma focuses project work on the identified variation from the proposed standard, this does not necessarily focus on customer requirements, instead sometimes focusing on cost-reductions which may lose sight of the customer, if not implemented alongside Agile.

Both approaches have the same objective function, which is achieving high quality. This is a crucial concept for the integration of the two improvement approaches, as a balance needs to be achieved between them. Moving extremely toward the Lean Six Sigma direction, increases the risk of being too rigid in responses to the market (lean) and subsequently impacting value creation. Also, focusing too much on decreasing variation beyond the requirements of the customer, and therefore wasting unimportant resources in the pursuit of minimal variation (six sigma) (Pepper & Spedding, n.d.). The other extreme is to focus on being too Agile and it is too expensive for the organization and the additional costs associated with risk abatement will be significant (Tan et al., 2008).

The balance lies in creating sufficient value from the customer's viewpoint while reducing variation to acceptable levels, so as to reduce costs incurred and maintain or grow market share, while at the same time being responsive to changes to the system.

Table 7 presents the usability of SWOT, which is a strategic analysis for Strengths, Weaknesses, Opportunities and Threats in the form of a matrix. Anthony (2011) gathered a precise review on Six Sigma and provided a SWOT analysis. We considered Agile, as well, and developed a novel SWOT matrix that considers both Agile and Lean Six Sigma in one matrix to present how these approaches relate to each other.

Table 7: SWOT matrix for improving an organization by showing the relation of Agile and Six Sigma principles.

Strengths			**Weaknesses**		
Agile	**LSS**		**Agile**	**LSS**	
✓	✓	**Customers are heard.**	✓		Team members need to be highly qualified and brilliant to success using its principles.
✓		Responsive and adaptable to sudden changes.	✓	✓	Time consuming.
✓	✓	Faster, high quality delivery.	✓	✓	High investment.
	✓	It has the ability of statistical thinking.	✓	✓	Requires infrastructural investment (money, time, etc.)
✓	✓	Capable of sustained response.	✓	✓	Requires statistical knowledge to apply the quantitative tools correctly.
✓	✓	It promotes the creation of continuous improvement.	✓	✓	Can be viewed as "elitist" by those not involved.
Opportunities			**Threats**		

Agile	LSS		Agile	LSS	
✓		Late changes are welcomed.	✓	✓	Lack of courses on Six Sigma in academic institutions.
	✓	Growing in some developing countries.	✓	✓	It may lose sight of what it is trying to achieve (sometimes something is just fine and does not need to be tweaked or improved).
✓		Early and predictable delivery.	✓	✓	Lack of visionary in many organizations
	✓	Developing and deploying in SMEs.	✓	✓	Expensive.
✓		Achieving reasonable results by forcing organization into a repetitive design or implementation.	✓	✓	Lack of collaboration between industrial and academic worlds.
✓		Predicting costs and schedule.	✓	✓	The empowerment of engineers and risk scientists may make managers afraid initially.
✓	✓	Developing many applications in public sector organizations.	✓	✓	Can be seen as “cumbersome”.

Based on the analysis in this paper, it is evident that Six Sigma offers a route to creating a stable, secure, and robust structure in any system that would benefit from reducing non-conformances, thus producing more reliable and consistent output. In a “steady state world,” this degree of resilience would suffice, but faced with unpredictable events, the system also needs to be agile and fast reactionary. The key mission lies in the usage of Agile and Lean Six Sigma together to increase control over the system and the ability to shift in output, as required, in order to neutralize any disruptive events to the system. As shown in Figures 4 and 5, adding Agile to Lean Six sigma approach can help any system adapt faster and ultimately be more efficient in providing service to customers.

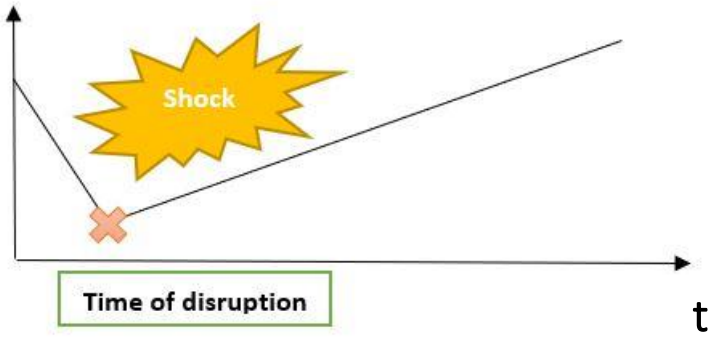

Figure 6: Before using Agile in an organization.

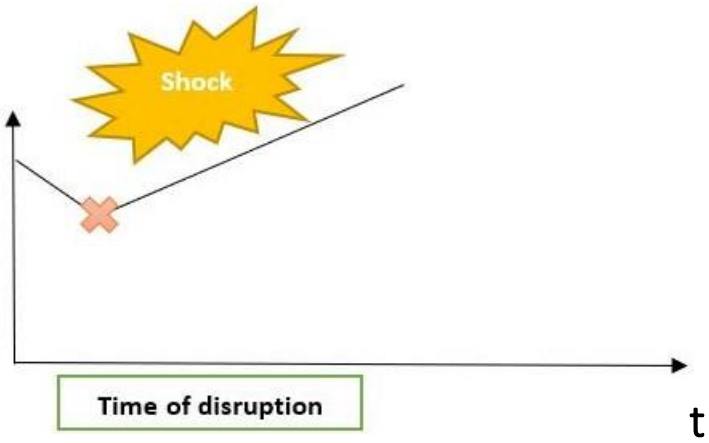

Figure 7: After using Agile in an organization.

Conclusions

The purpose of this paper is to describe strengths, weaknesses, threats, and opportunities of Agile and Lean Six Sigma together. It is the authors' recommendation that there is a lot to gain if organizations are able to combine these concepts. Indeed, the concepts are complementary; especially Agile is an excellent strategy, which could be combined with LSS, in order to strengthen the values of an organization.

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