Comparative Analysis of Lean and Six Sigma in Building Construction: Benefits, Obstacles and Opportunities

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Abstract: Lean and Six Sigma have been recognized as innovative strategies that can be used to transform a firm's management practices to a newer level. However, there is little guidance, or evidence indicating whether Lean or Six Sigma enhance the construction process significantly. This research fills this gap by investigating major obstacles, benefits and opportunities of Lean and Six Sigma as published in journal papers. A structured literature research (SLR) was performed to identify and compare lean and Six Sigma case studies and analyzed their findings and conclusions. This SLR resulted in a matrix that identifies the obstacles, benefits and opportunities of using Six Sigma and lean practices to assist industry practitioners adopt and implement these strategies.

Keywords: Lean, Six Sigma, Project Management, Structured Literature Research

Introduction

Research indicates that Six Sigma is a process used extensively in the manufacturing, health, pharmaceutical, heavy engineering, computing, information technologies and other process and product intensive industries. Lean theories and practices came up mostly from the automotive manufacturing industry but is currently being adopted by the vertical and horizontal construction industry. There is a third aspect, lean six sigma, a less intensive six sigma version that is also being considered for adoption by the construction industry. This paper identifies the main research work in these three areas and proposed a comparative method that visualizes the similarities and differences between the three. This paper also serve as a decision support system to companies interested in adopting one or more of these theories into their practice.

Six Sigma

Six Sigma is a theory technique and best practices aimed to assist project design and executions deliver accelerated business results in the form of less time, less waste and less cost. Six Sigma is a disciplined data driven approach methodology for elimination of defects in any process. By data driven is the practice to measure everything in order to logically find an otherwise hidden wasteful practice. The main principle of lean project management is delivering more value through the discovery and elimination of embedded material or process waste.

An essential element to assuring six-sigma success is in ensuring that its practices are used beyond production. For example not only design and construction but also land development, marketing, sales, estimating, design, purchasing, construction, warranty and service to finance and administration - all need to be introduced to the Six Sigma concepts, theories and practices.

Lean Six Sigma

Lean Six Sigma (LSS) is a business improvement methodology (Pamfilie et al. 2012) that integrates two distinctive management philosophies: Lean and Six-sigma (Pepper and Spedding 2010) complementing each other to improve Project Management processes by reducing non-productive time and other wastes. The LSS integration is achieved by combining their respective methods and principles (George 2003). The key to this combination is called **DMAIC** (define, measure, analyze, improve, control) cycle, a continuous improvement framework (Cheng and Chang 2012). DMAIC aims to reduce production defects and process variability, along with process simplification, standardization and waste reduction (Zhang et al. 2011), see Fig. 1.

(Source: www.goleansixsigma.com)

Fig. 1 Golean Six Sigma Process

Until 1900, civil engineering projects were generally managed by creative architects, engineers, and master builders themselves. It was in the 1950s that design and construction companies started to systematically apply project management tools and techniques to complex engineering projects. As a discipline, project management developed from several fields of application including civil construction, engineering and heavy defense activity (Kwak 2005).

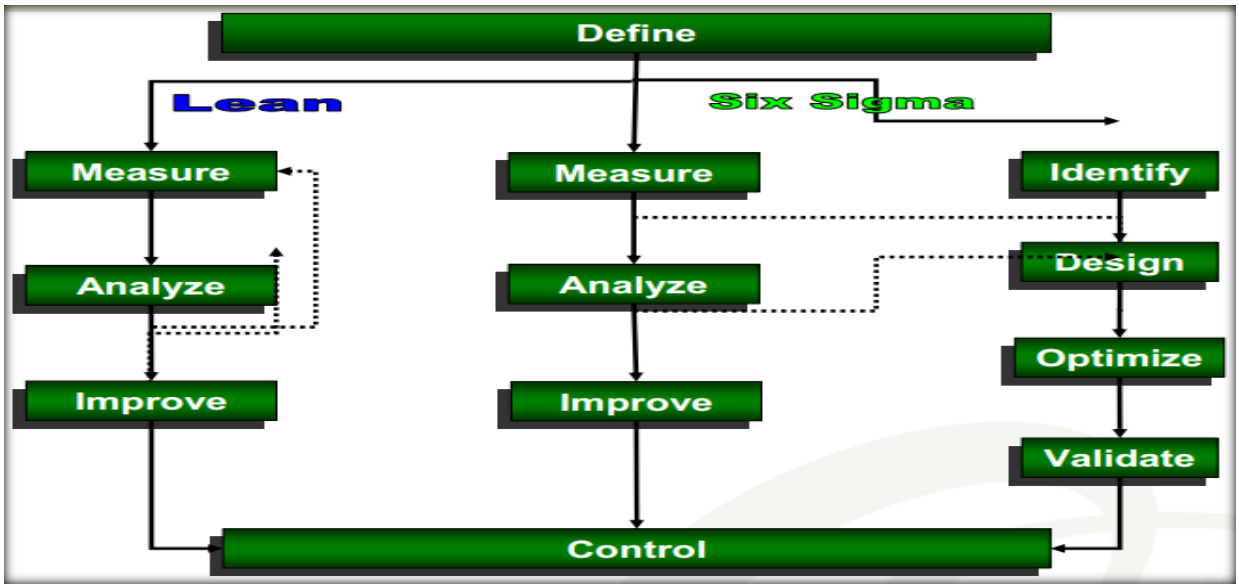
Cyclical economic crises raise the constant demand for profitable solutions that allow company organizations to gain competitive advantage. However, since 1950, project failures continued at an alarming rate, despite growing understanding of determinants of success in project management, increasing maturity, and a stream of successful projects. Statistics of challenged and failed projects testify that these failures are much more common (Anbari 2003), as compared to the widely reported success rate of projects that used Six Sigma approach to design and construction. For this reason, more and more companies searched and demanded new management methodologies that allow them to improve their products and/or service characteristics, perfect their processes, decrease costs, improve the capital's profitability and costumers' satisfaction. For example the automotive industry in the USA took notice of the lean practices of Toyota that resulted in a product of much higher quality and standards that eventually diminished USA market dominance.

Many construction projects suffer delays from variability stemming from single or multiple causes. An associated principle with waste removal is variability reduction (Bertselen and Koskela 2002). In the construction industry, sources of variability include late delivery of material and equipment, design errors, change orders, equipment breakdowns, tool malfunctions, improper crew utilization, labor strikes, environmental effects, poorly designed production system, accidents, and physical demands of work (Abdelhamid and Everett 2002).

ADD pareto figure.

This have been attempted through Lean management and Six Sigma integrated approaches in their managerial and production processes in which, Lean focus mainly on the waste elimination,

using simple and visual techniques whenever possible and Six Sigma on the control and processes variability reduction, using statistical tools for this purpose (Tenera and Pinto 2003).



(Source: www.goleansixsigma.com)

REVIEW OF LITERATURE:

Benefits and savings of implementing the project-driven Six Sigma method have been widely reported. Organizations' benefits, improvements, and savings have been achieved by implementing the Six Sigma method in the manufacturing sector, based on extensive investigation of literature on Six Sigma (Weiner 2004, De Feo and Bar-El 2002, Anthony and Banuelas 2002, Buss and Ivey 2001, and McClusky 2000).

The obstacles to Lean Enterprise identified by Henderson and Larco (2000) are stated as follows:

- Lack of strategic understanding of Lean Enterprise in the top management.
- Lack of specific Lean Enterprise skills, knowledge
- Culture, ego, and organizational inertness
- Reluctance to empower people by management
- Fear of change, loss of organizational power
- "Not invented here" syndrome
- Internal systems and hurdles, specifically
    - Inflexible accounting methods
    - Severely disjointed plant operations

These obstacles encompass both deployment barriers and implementation challenges. Henderson and Larco's (2000) first obstacle, "Top management lack strategic understanding of Lean Enterprise" commonly occurs during both the deployment and implementation phase but should be addressed during deployment. Reluctance to empower, fear of change, and loss of power are also deployment barriers. The internal systems and hurdles listed above are good examples of implementation challenges.

More specifically, deployment barriers identified by Snee (2003) include: uncommitted leadership, top talent not selected to lead efforts, and lack of infrastructure support.

Uncommitted leadership and top talent not selected to lead efforts would be considered as deployment barriers and researchers would categorize "lack of infrastructure" as an implementation challenge.

Liker and Choi (1998) defined implementation challenges of continuous improvement programs as:

- Employee's resistance towards change
- Line managers' difficulty in managing production and continuous improvement efforts
- Production gets in the way of the top manager's vision of launching continuous improvement projects
- Lack of management to spread continuous improvement throughout the organization
- Lack of management to allow worker participation
- Lack of integration of continuous improvement teams with normal workers
- Internal political tension
- Lack of management support for continuous improvement efforts
- Trying to sell and implement continuous improvement changes without management support

The use of either Lean or Six Sigma can cause firms to put incorrect priority on certain improvement initiatives, while LSS can solve such a problem because: "The activities that cause the customer's critical-to-quality issues and create the longest time delays in any process offer the greatest opportunity for improvement in cost, quality, capital, and lead time" (George 2002). Hence, a synergy should be obtained which results in better overall performances rather than individual approaches to process improvement (Brett & Queen, 2005). Lean Six Sigma (LSS) emerges from the integration of the lean manufacturing production system with the efficient Six Sigma improvement methodology. Snee (2010) defines LSS as a business strategy and at the same time a methodology that increases process performance, resulting in greater client satisfaction and results. In a theoretical conceptual study, Arnheiter and Maleyeff (2005) found that LSS leads to an incremental increase in the level of quality of the products and reliability of processes and thus supports the implementation of lean practices like TPM and others.

Table 1: Lean Matrix

Paper	Author	Benefits			Obstacles			Opport.	No. of time cited
		Waste Reduction	Variability Reduction	Cost Savings Schedule	Specialized Training	Management Commitment	Cultural Change	Mentions Six Sigma	
Site Implementation and Assessment of Lean Construction Techniques	O. Salem, J. Solomon, A. Genaidy and I. Minkarah	**Y**		**Y**	**Y**	**Y**			156
A framework to improve construction processes: Integrating Lean, Green and Six Sigma	Abdulaziz Banawi & Melissa M. Bilec	**Y**	**Y**					**Y**	9
Analysis of Lean Construction Practices at Abu Dhabi Construction Industry	Raid Al-Aomar	**Y**		**Y**	**Y**	**Y**	**Y**	**Y**	6
Competing Construction Management Paradigms	Glenn Ballard and Gregory A. Howell	**Y**		**Y**					93
Interaction of Lean and Building Information Modeling in Construction	Rafael Sacks, Lauri Koskela, Bhargav A. Dave and Robert Owen	**Y**	**Y**	**Y**					166
Site Implementation and Assessment of Lean Construction Techniques	O. Salem, M. Luering and J. Solomon	**Y**			**Y**		**Y**		77
Lean Construction with or without Lean - Challenges of Implementation Lean Construction	Soren Wandahl	**Y**			**Y**	**Y**	**Y**		156
Why isn`t the UK Construction Industry going Lean with gusto?	Alan Mossman	**Y**	**Y**	**Y**	**Y**	**Y**			42
Lean principles in industrialized housing production: the need for a cultural change	Matilda Hook and Lars Stehn	**Y**	**Y**			**Y**	**Y**		53
The evolution of Lean Six Sigma	M.P. J. Pepper and T.A. Spedding	**Y**		**Y**		**Y**	**Y**	**Y**	188

Table 2: Six Sigma matrix

Paper	Author	Benefits			Obstacles			Opport.	No. of times cited
		Waste Reduction	Variability Reduction	Cost Savings/Schedule	Specialized Training	Management Commitment	Cultural Change	Mentions Lean	
Six Sigma Based Approach to Improve Performance in Construction Operations	Seung Heon Han, Myung Jin Chae, Keon Soon Im and Ho Dong Ryu		**Y**					**Y**	40
Implementing and Applying Six Sigma in Construction	Low Sui Pheng and Mok Sze Hui		**Y**		**Y**	**Y**	**Y**		69
Benefits, Obstacles and future of Six Sigma approach	Young Hoon Kwak, Frank T. Anbari		**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	531
Performance Improvement in Construction Project based on Six Sigma Principles	Maryam Dabbaghi Tehrani		**Y**	**Y**	**Y**	**Y**			0
Critical success factors for the successful implementation of Six Sigma projects in organisations	Ricardo Banuelas Coronado and Fiju Antony		**Y**		**Y**	**Y**	**Y**		127
Integration of Lean Management and Six Sigma	Edward D. Arnheiter and John Maleyeff	**Y**	**Y**	**Y**	**Y**		**Y**	**Y**	416
A Comparative Analysis of Application of Six Sigma Project Management Technique in Small and Medium Scale Construction Companies in Nigeria	V. O. Okonkwo and V. M. Mbachu	**Y**	**Y**	**Y**					0
Critical Success Factors for Six Sigma Implementation in Large-Scale Turkish Construction Companies	Mehmet Tolga Taner	**Y**	**Y**		**Y**	**Y**			3
Managing Concrete Crack Information through Correction of the Slab Rebar Arrangement based on Six Sigma	S. J. Eom, Won-Suk Jang and Sang-chul Kim		**Y**					**Y**	1
Process and Quality Improvement Using Six Sigma in Construction Industry	Megan Florent Tchidi, Zhen He and Yan Bo Li	**Y**	**Y**	**Y**	**Y**				12

FINDINGS:

SLR was conducted to formulate a matrix. It was found that the published literature work on Lean and Six Sigma talk about similar challenges that are faced while implementing these techniques. Although the challenges are similar, significant benefits were cited by using Lean and Six Sigma techniques individually. It was also found by the literature search that Lean papers mention using Six Sigma approach as an innovative strategy. Additionally, Six Sigma papers also mention about improvement in the practice by incorporating Lean principles. This SLR may serve as the decision support model for selection of most optimum strategy utilizing the matrix produced comparing Lean and Six Sigma, for construction process improvement.

CONCLUSION

Implementing the Lean techniques have helped significantly reduce wastes in the construction process. Also, as a business approach Six Sigma has proved its beneficial use by notably minimizing the variability and improving sigma level in the construction process. Both paradigms face similar challenges which can be overcome jointly. The two models are prominent catalysts of change as stand-alone methods, but have a potential to become a very significant and powerful tool if combined together. This will have a greater advantage on the construction process improvement by achieving combined benefits by utilizing principles from both the strategies.

In conclusion, if Six Sigma is implemented without Lean, the system would lack tools and structure to drive the process towards high value and waste reduction. Conversely, if Lean is adopted without Six Sigma, the process will need a strategy to steer it towards high cost savings and variability reduction. Hence, a closely integrated and unified methodology should be adopted reinforcing Lean principles and Six Sigma strategy for the process improvement.

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