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Applying Lean Six Sigma within the university: opportunities for process improvement and cultural change

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Abstract

Purpose – The purpose of this paper is to review the historical development of Lean Six Sigma and to identify the relevant opportunities for the application of Lean Six Sigma within the university setting. The paper also discusses the challenges of Lean Six Sigma implementation in higher education, as well as the cultural changes necessary to provide an appropriate climate for its long-term success.

Design/methodology/approach – The paper contains a comprehensive discussion of the development of Lean Six Sigma over the past three decades. Additionally, the paper describes how Lean Six Sigma may be applied in the university setting to improve processes in curriculum delivery; business and auxiliary services; admissions and enrollment management; and research.

Findings – Lean Six Sigma can be applied to facilitate process improvements in curriculum delivery; business and auxiliary services; admissions and enrollment management; and research. While obstacles to Lean Six Sigma implementation exist, the process improvements and resulting cultural changes are worthwhile and noteworthy.

Research limitations/implications – The paper serves as a guide for how Lean Six Sigma processes can be utilized in the higher education setting. Other researchers and practitioners may use the paper as a practical orientation to Lean Six Sigma in the university setting.

Originality/value – Due to the unique culture of higher education, the application of Lean Six Sigma to university processes has been sparse. The paper provides a needed orientation as to how Lean Six Sigma may be applied to improve some of the more important functional aspects of the university.

Keywords Lean Six Sigma, Higher education

Paper type Conceptual paper

Introduction

While Lean Six Sigma continues to gain popularity and acceptance in the business, industry and manufacturing sectors, the process improvement methodology has received only passing attention within the higher education domain. As a result, there is little research available on how Lean Six Sigma may be applied to improve the processes within the university setting. Given the escalating costs and declining revenue streams currently facing both public and private higher education institutions,

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the benefits to be gained through the utilization of Lean Six Sigma would appear to be both obvious and pressing (Bandyopadhyay and Lichtman, 2007). However, higher education institutions have been steeped in traditions that have insulated them from the organizational and cultural changes visited upon the business and manufacturing sectors.

The current economic environment in which universities must operate, including reduced appropriations and increased labor costs, creates a unique opportunity for administrators and faculty to collaborate on process improvement. Students desire both a more relevant curriculum, and one that will accelerate their educational process. Regents, trustees and administrators desire to demonstrate that investments made by funders are well-managed and effective. University business officers desire methods that will streamline financial processes resulting in expense reductions. Faculty desire opportunities to enhance their role and relevance in the university setting. Collectively, these conditions provide a climate for not only the application of Lean Six Sigma, but also the initiation of the cultural changes needed to enable Lean Six Sigma to succeed in the unique environment of higher education.

Purpose of paper

The purpose of this paper is to review the historical development of Lean Six Sigma and to identify the relevant opportunities for the application of Lean Six Sigma within the university setting. The paper also discusses the challenges of Lean Six Sigma implementation in higher education, as well as the cultural changes necessary to provide an appropriate climate for its long-term success.

Evolution of Six Sigma, Lean and Lean Six Sigma

Six Sigma

Six Sigma was first conceptualized in the mid-1980s as a business process improvement model by Bill Smith, a reliability engineer at Motorola, Inc. (Brady and Allen, 2006) The concept was subsequently implemented at Motorola by CEO Robert Galvin as a ubiquitous internal strategy to revitalize the company (Brady and Allen, 2006). Six Sigma received even greater notoriety in the 1990s when it was implemented at the General Electric Company by then CEO Jack Welch as a company-wide approach to quality improvement (Brady and Allen, 2006). Since that time, Six Sigma has achieved greater appeal to many business enterprises, more so than Total Quality Management (TQM), because of Six Sigma's focus on measurable results and its disciplined data-based approach to problem solving and process improvement (Barney, 2002).

In its purest form, Six Sigma is a process improvement model designed to address four key initiatives: *Quality, Productivity, Cost and Profitability* (Bandyopadhyay and Lichtman, 2007). More specifically, the process is a determined and intensive effort to:

- find and eliminate causes of defects and errors;
- reduce cycle times and cost of operations;
- improve productivity;
- achieve higher asset utilization; and
- better meet customer expectations (Bandyopadhyay and Lichtman, 2007).

Six Sigma focuses on reducing the variation in the production process through the use of statistical tools such as process capability analysis, cause-and-effect diagramming and statistical process control (Young, 2002). Additionally, Six Sigma determines to improve product design to meet or exceed customers' expectations by using methods such as Quality Function Deployment (QFD), Taguchi's methods of product design and robust design. (Treichler *et al.*, 2002).

The foundation of the Six Sigma process is a problem-solving approach summarized by the acronym "DMAIC", defined as Define, Measure, Analyze, Improve and Control, each incorporating a number of statistical and quality improvement tools and techniques (Pande *et al.*, 2000; Andersson *et al.*, 2006). The five-step, problem-solving process as outlined by the authors is more fully explained below:

(1) *Define*: Defines who the customers are, what the customers want, the process capabilities and provides objectives for project-based improvement efforts.

(2) *Measure*: Measures the quality characteristics that reflect improvement in customer satisfaction and product performance and provide the metrics of data upon which the improvement efforts will be based.

(3) *Analyze*: Data collected from pervious steps are fully analyzed using analytical tools such as Pareto analysis, process flow diagrams, fish-bone diagrams and statistical process control charts, for identifying necessary design and process modifications for achieving customer satisfaction and performance objectives.

(4) *Improve*: Allocates resource so that design and process modifications needed for improvement may be implemented.

(5) *Control*: Processes are monitored using quality management tools and statistical process control charts to ensure performance improvements are maintained (Pande *et al.*, 2000; Andersson *et al.*, 2006).

Lean

The roots of Lean philosophy, as contemporarily described by Womack and Jones (1996), may be historically traced to the Toyota Production System (TPS), begun shortly after World War II. Pioneered by Taiichi Ohno and others at the Toyota Motor Company, TPS was developed in reaction to shortages in capital and material resources (Russell and Taylor, 2000). The goal of the system was to eliminate all waste in the manufacturing process and to add value to the finished product (Russell and Taylor, 2000), and its end result was a new manufacturing paradigm – the TPS (White and Prybutok, 2001). Subsequently, a benchmarking study undertaken by the International Motor Vehicle Program (IMVP), and the academic work of Womack *et al.* (1990), convinced companies around the globe to adopt the principles of the TPS. These adoptions were primarily motivated by competitive concerns and were popularized under the umbrella of just-in-time (JIT) (Pepper and Spedding, 2010).

Lean manufacturing extended the reach of the TPS by providing an enterprise-wide perspective on "the product development process, the supplier management process, the customer management process, and the policy focusing process for the whole enterprise" (Holweg, 2007). The individual product and its value stream is the foundation of this vision, identifying value-added and non-value-added activities, as well as to eliminate all waste in the production process (Womack and Jones, 1996). Waste within the system may be categorized in one of the following:

- over-production;
- defects;
- unnecessary inventory;
- inappropriate processing;
- excessive transportation;
- waiting; and
- unnecessary motion (Womack and Jones, 1996).

The initial effort in the development of a Lean system is the identification of processes which add value and those that do not. Value stream mapping (VSM) has evolved as the primary process to accomplish this task (Rother and Shook, 1999). One of the primary benefits of VSM is that it provides a common language when considering manufacturing processes. Rother and Shook's (1999) work in VSM brought together all of the Lean techniques and depicted the linkages between information and material.

However, VSM is not without critics. Sheridan (2000) noted that the practical nature of VSM (i.e. the paper-and-pencil approach) limited the amount of detail collected, thereby detracting from the actual workings of the system. Sheridan (2000) concluded that VSM should be utilized as a continuous tool, constantly updated via software applications.

Others also contended the utilization of software tools could increase the amount of data that could be presented and analyzed. McDonald *et al.* (2002), Lian and Landeghem (2002) and Abdulmalek and Rajgopal (2007) have researched the utilization of computer simulation techniques to strengthen the VSM integration process. However, there is a trade-off in the use of complicated software products. Complex analysis made possible by simulation can add months to the VSM process, costing valuable time and the loss of crucial momentum (Pepper and Spedding, 2010).

Simply mapping a value stream does not constitute Lean. Rather, the Lean philosophy must be viewed as a system, of which VSM is a single component (Pepper and Spedding, 2010). To achieve a truly Lean operation, VSM needs to be methodically applied before other tools such as single-minute exchange of die (SMED) and 5S are applied (Pepper and Spedding, 2010). The most ubiquitous of the Lean tools is 5S, which condones cultural change in the organization, making systematic and standardized processes part of the normal routine rather than the exception (Pepper and Spedding, 2010).

Bicheno (2010) described 5S as fundamental to achieving a Lean business, equally applicable to all aspects of the business enterprise. Pepper and Spedding (2010) stressed that implementing 5S singularly or prematurely before other Lean tools creates the erroneous impression that the focus of improvement is consumed with 5S, thereby detracting from the rest of the viable Lean techniques. The authors further concluded that 5S was a powerful approach, but it is self-limiting, unless implemented as part of a comprehensive initiative.

Among the most successful Lean initiatives are those implemented in the automotive and aerospace industries, including Mitsubishi, Volvo and Chrysler (Fitzgerald, 1997). The Delphi Corporation initiated a comprehensive Lean program led by top executives which included suppliers, strategic sourcing and cost management (Nelson, 2004).

The development of diverse Lean tools has also created a plethora of applied research opportunities within the academic community. Some of the more notable include 5S (Warwood and Knowles, 2004), total production maintenance (TPM) (Bamber *et al.*, 1999), SMED (Mileham *et al.*, 1999; Ireland and Dale, 2001) and VSM (McDonald *et al.*, 2002; Abdulmalek and Rajgopal, 2007).

Lean Six Sigma

Lean Six Sigma is the integration of Lean and Six Sigma philosophies (Sheridan, 2000). Given the fact that Lean Six Sigma is still relatively new to the process improvement world, it has yet to receive the full attention of academic researchers (Bendell, 2006). Smith (2003) concluded that the majority of efforts to fully and comprehensively implement a Lean Six Sigma initiative have yet to be fully realized. Smith (2003) further noted that Lean and Six Sigma are often implemented in isolation of one another. Bendell (2006) noted that this isolation creates conflicts within the organization, as well as a drain on company resources.

Six Sigma complements Lean philosophy in as much as providing the tools and knowledge to address specific problems that are identified along the Lean journey (Pepper and Spedding, 2010). "Lean eliminates 'noise' and establishes a standard" (Wheat *et al.*, 2003). Lean also assists in maintaining a customer focus to prevent a singular Six Sigma initiative from becoming a cost-reduction exercise (Bendell, 2005). Arnheiter and Maleyeff (2005) outlined the benefits of the integration of Lean and Six Sigma, noting that the scientific and measurements perspective of Six Sigma keeps Lean processes on target and eliminates wastes through more accurate processing. Pepper and Spedding (2010) concluded that Lean and Six Sigma are ideally suited to be used in a comprehensive methodology incorporating the key elements of both, as each stage can gain from the respective techniques, both following the Six Sigma road map of define, measure, analyze, improve and control.

Higgins (2005) noted that while Six Sigma is often implemented by a few specific individuals within a company, Lean perpetuates the empowerment of everyone in the organization to identify and eliminate non-value-adding activities. The integration of the two methodologies attempts to provide empowerment even at the higher-level process analysis stages, so that employees have true ownership of the process (Pepper and Spedding, 2010). Conversely, when the two are implemented in isolation, the result is neither being done effectively (Harrison, 2006). Both approaches are effective on their own, but organizations may well find that after initial improvement, they reach a plateau, and find it difficult to create an ongoing culture of continuous improvement (CI; Arnheiter and Maleyeff, 2005). The Lean approach is benefited by Six Sigma's use of targeted data to make decisions and also adopt a more scientific approach to quality within the system. Likewise, Six Sigma benefits from the wider systems approach of Lean in considering the effects of waste on quality and variation levels of the system as a whole (Arnheiter and Maleyeff, 2005).

Pepper and Spedding (2010) posited that the application of Lean tools and techniques identifies key areas that can be leveraged by Six Sigma. Further, they concluded that Lean techniques are best used to consider and improve the organization on an operational level through the targeted removal of non-value-adding activities:

> From this reduction in complexity, Lean identifies opportunities for improvement that can then be leveraged through the application of high powered, more focused, Six Sigma

techniques, driving the improvement of the system further towards a Lean environment (Pepper and Spedding, 2010).

Sharma (2003) described the benefits of an integrated Lean Six Sigma methodology, whereby strategic improvement goals are established by the company's leaders, and then a process of QFD is used to prioritize the project work. The QFD approach can also be viewed as a more complicated approach to the selection of CI tools (Pepper and Spedding, 2010).

The integration of Lean Six Sigma has received some criticism in the literature. Bendell (2006) believed that Lean and Six Sigma have evolved into "ill-defined philosophies", resulting in their dilution as effective tools due to a lack of specific company training programs. He further suggested that a single and accepted approach bringing the two methodologies together would beneficial to all. Mika (2006) argued that Lean and Six Sigma are completely incompatible due to the fact that the complexity of Six Sigma prevents its understanding and acceptance by the average manufacturing worker, while Lean is understood and embraced by these workers.

The work of Kumar *et al.* (2006) provides some of the most comprehensive perspectives for both practitioners and researchers of Lean Six Sigma. Some of the key conclusions include:

- there is no standard framework for Lean Six Sigma;
- there is no clear understanding concerning the usage of tools, etc., within the Lean Six Sigma frameworks; and
- there is no clear direction as to which strategy should be selected in the early stages of a project (Kumar *et al.*, 2006).

Pepper and Spedding (2010) provide important conclusive thoughts on Lean Six Sigma integration. The authors note that Lean has moved away from being a cure-all philosophy; rather, Lean Six Sigma should be seen as the platform for the initiation of cultural and operational change, leading to total supply chain transformation. Further, Pepper and Spedding (2010) concluded that when used in combination with other complementary CI techniques such as Six Sigma, Lean provides "a more integrated, coherent and holistic approach to continuous improvement".

Lean Six Sigma in higher education

The great majority of quality initiatives implemented in higher education institutions within the USA over the past two decades have focused on the TQM and CI methodologies (Bandyopadhyay and Lichtman, 2007). Given the pressures of lower productivity and declining revenue streams, higher education institutions should be aggressively pursuing the benefits provided by Lean Six Sigma (Bandyopadhyay and Lichtman, 2007). Bandyopadhyay and Lichtman (2007) also described an approach focusing on the CI of educational program design processes utilizing QFD. This methodology outlined the inclusion of a number of both internal and external stake holders in a continuous program design and evaluation process to ensure that the needs of the customers were met or exceeded (Bandyopadhyay and Lichtman, 2007).

Raifsnider and Kurt (2004) indicated that the Six Sigma methodology would be applicable to higher education but the lens from which they viewed the application was limited to an administrative setting. Quinn *et al.* (2009) examined techniques for

measuring and improving service quality in higher education, including: TQM; QFD; Six Sigma; ISO 9001; The Malcolm Baldrige National Quality Award; and The Academic Quality Improvement Program (AQIP). The authors found that TQM has been widely used, QFD is gaining in popularity and the use of Six Sigma has not been reported in the higher education quality literature. While many higher education institutions have used a variety of methods to pursue quality improvement, similar obstacles have been encountered by those institutions (Quinn *et al.*, 2009). Those common obstacles include customer definition, shared decision making, resistance to industry techniques and resistance to change (Quinn *et al.*, 2009).

Antony *et al.* (2012) acknowledged the applicability of Lean Six Sigma to the university setting, but identified a number of challenges to doing so. The authors noted that the culture of most institutions of higher education served as the major barrier for successful Lean Six Sigma implementation and proposed the development of an assessment instrument to determine overall organizational readiness.

Lean Six Sigma and the university enterprise

Institutions of higher education share the strategic vision of providing the highest quality education possible for their students. Indeed many, if not most, institutional mission statements include such a reference as their primary focus. Given this perspective, needs and interests of the student or "customer" should create an environment for institutional change and improvement. This student focus is the premise and rationale for why Lean Six Sigma should be injected throughout the higher education system.

To fully discuss the potential impact of Lean Six Sigma on the university, it is important to describe where the greatest opportunities exist. For this reason, the institutional functions to be discussed here are:

- curriculum delivery;
- business and auxiliary services;
- admissions, enrollment management and marketing; and
- research.

Curriculum delivery

Arguably, the basic methods of earning a college degree have not changed significantly over the past five decades; perhaps longer. While most universities have adopted a variety of new technologies, and the advent of the personal computer and the Internet have had a dramatic impact on individual course delivery, in general the timing and format for the delivery of an entire degree program has not evolved at the same pace as the technology.

The semester and credit-hour format are long-standing traditions of the higher education culture. This format, while convenient for faculty, administrators and tuition billing systems, does not necessarily fit the needs of the student. Students might prefer open-ended course enrollment and credits awarded based on demonstrated competencies, irrespective of semester timing. Although the university may have all the assets necessary to deliver the curriculum in this alternative manner, all of its processes, from enrollment to graduation, are designed around the semester system. To change for the betterment of the student, an academic process improvement and resource allocation

project would have to be undertaken. While recognizing the size and scope of such an effort, this is an ideal setting for the implementation of Lean Six Sigma.

The following statements encapsulate some of the Lean Six Sigma opportunities in the curriculum delivery process:

(1) Lean Six Sigma processes are ideal for the establishment of student competency definitions for the curriculum. Ostensibly, university curriculum is designed to prepare a student for the next life experience, whether it be a professional career or the pursuit of an advanced degree. While some might argue that a college degree is an end to itself, very few college students would be willing to assume a significant debt load without the promise of a career path to repay the obligation. Lean Six Sigma methodologies can be applied to determine the most appropriate preparation and competencies for the degree path.

Lean Six Sigma in this endeavor would enable administrators and faculty to recognize the importance of external customers, specifically those who will be employing the graduate or those graduate schools who will be accepting them. The Lean Six Sigma methodology applied here would:

- measure current rates of success in both employment placement and graduate school acceptance;
- identify the major external customers (major employers, graduate and professional schools) and engage those customers on their expectations for competencies of graduates; and
- utilize those expectations to derive the most appropriate instructional modules and delivery system for the curriculum.

(2) Lean Six Sigma analyses could be utilized to analyze and measure the variations in student performance. Once determined, the application of competency-based instruction methodologies could be implemented and tested as a means of lowering error rates and grade subjectivity appeals. Additionally, acceleration of the learning process could be tested using the competency-based instruction method. The ultimate goal here of course is to reduce the time necessary to earn an undergraduate or graduate degree.

(3) In tandem with the curriculum delivery improvement process, Lean Six Sigma processes could be initiated to address the faculty resource allocation issues within the university. Given that faculty costs represent the single greatest budget investment, the eternal question that has always plagued administrators is "how can this investment be best utilized?" The Lean Six Sigma process would enable administrators and faculty alike to view the talent pool of faculty as a resource to be applied for the ultimate benefit of student customers, while supporting the faculty career path. Because faculty are expected to accomplish a number of tasks simultaneously, such as instruction, research and service/outreach, they are reluctant to engage in dialogue or processes that threaten their ability to achieve and retain their tenure status. So long as research and publication are valued more than instruction, faculty will be reticent of any effort to decrease their ability to pursue these objectives.

Lean processes would enable the administration and faculty functioning as a project team to create a matrix addressing faculty time and university goals. A

Lean Six Sigma faculty resource matrix process would view the instruction, service and research goals of the university as global tasks that would allow faculty resources to be applied collectively, rather than tasking each individual faculty with the same load of instruction, service and service responsibilities. Using Lean Six Sigma methodologies would create more flexibility on matching the talents of faculty members with the initiatives of the university. Promotion and tenure guidelines could be viewed as a process review initiative, the desired result being a promotion and tenure policy that recognizes the individual strengths of faculty and rewards those attributes. An example of a Lean Six Sigma result might be a participatory promotion and tenure policy review that rewards *senior* faculty for their participation in freshman instruction, giving new students exposure to the best faculty. This "no rookies on rookies" policy could not only alter the faculty's attitude toward classroom instruction, but could also raise retention rates for new students.

Business and auxiliary services

The financial model for every university, whether public or private, is based on the premise of maximizing and diversifying the revenue stream to keep pace with the escalating costs of the enterprise. When the university's revenue streams are static or declining, the only alternative is to reduce the annual expense load of the system. Traditionally, fiscal officers have been trained to approach the expense reduction exercise as a "C-Suite" activity, discussed and accomplished at the highest levels of the organization. However, the Lean Six Sigma methodology applied to the revenue and expense cycle could arguably produce a better outcome. Even if the outcome has negative consequences, the processes inherent to Lean Six Sigma are likely to produce a result that is better understood and accepted. Consider the following business and auxiliary services opportunities from the Lean Six Sigma perspective:

(1) Revenue cycle enhancements are vital to the financial viability of the university business enterprise. The timing of the receipt of tuition and fees is a process that Lean Six Sigma can substantially improve by:
   - utilizing Lean Six Sigma techniques to detail and analyze the optimal tuition payment policies, these processes would answer the questions relating to the impact of payment-plans on student enrollment;
   - analyzing the appropriate blend of tuition and fees on price resistance;
   - determining the impact of student loan debt on future enrollment; and
   - applying Lean Six Sigma to the improvement of billing and payment receipt processes to lower the cost of bursar personnel.

(2) Expense reductions are fast becoming a central focus of the university business office. Lean Six Sigma processes may be applied to identify and implement major cost reduction efforts. Some of the more pressing Lean Six Sigma opportunities in this realm include:
   - applying Lean Six Sigma statistical analysis to energy consumption across the campus to identify those areas where efficiencies may be gained;
   - utilizing Lean Six Sigma to determine the most appropriate energy supplier in a deregulated environment;

- using Lean Six Sigma to analyze purchasing cost variances in all supply and material contracts, as well as to identify where contract consolidations could produce savings;
- analyzing work flow and staffing patterns across all campus departments to determine where pooled staff, job sharing and seasonal adjustments could lower overall personnel costs; and
- applying Lean Six Sigma processes to determine which auxiliary functions (housing, food service, security, housekeeping and physical plant maintenance) are best handled with university-employed staff or contracted services.

Admissions, enrollment management and marketing

The ability to attract and retain students is pivotal to the overall success of the university enterprise. Nothing can shake the foundation of the university community more than a drop in student enrollment. In past decades, little attention was paid to the admissions, enrollment management and marketing functions until an enrollment decrease occurred. In the current economic climate, university administrators and governing boards are keenly focused on the admissions process, often monitoring enrollment statistics and recruitment data on a daily basis.

Given the fact that these functions have the attention of institutional leaders, Lean Six Sigma may have a head start in successful implementation. Moreover, as the availability of data is a key component of Lean Six Sigma, the current efforts of most universities to aggressively track and monitor admissions and enrollment data are fortuitous. The Lean Six Sigma opportunities in admissions, enrollment and marketing are ripe for realization. The following concepts represent just a few of those opportunities:

- The statistical techniques of Lean Six Sigma may be applied to admissions and marketing data to determine and lower the variation rate in the amount of marketing funds expended per admitted student. This type of analysis would allow admissions officers to effectively measure the success rate of expended funds in specific markets, thereby making the best use of available funding. The same statistical techniques could be applied to the analysis of direct mail, e-mail, social media and telephone recruiting processes to identify, modify or validate current marketing initiatives.
- The Lean Six Sigma methodology is equally suitable for the implementation and/or evaluation of retention programs. As many institutions have concerns over dropout rates, analysis of processes that contribute to or deter student withdrawals is critical to the enrollment management program. Lean Six Sigma would allow administrators to go beyond the typical reporting of the number of students withdrawn, instead focusing on the processes that can be implemented to prevent the occurrence.
- Lean Six Sigma processes would allow the admissions and enrollment management process to be viewed as an institution-wide process, rather than simply the function of a single unit. Additionally, process improvement methodologies would allow the culture of enrollment management to be integrated throughout the campus, involving faculty, support and students

themselves. The Lean Six Sigma perspective of resource allocation to problem solving would facilitate the use of process improvement teams, staffed by administrators, faculty, support staff and students, to identify intuitive initiatives to attract new students to the campus and to retain those students already enrolled.

Research

Once viewed as an academic exercise of the faculty, the research function of the university has evolved into a business enterprise focused on revenue and idea production. Universities now consistently rely on research production as a means of producing revenue from federal, state and private sources, as well as to produce new technology for patenting and licensing. While some in the academic community might argue that research is conducted for the purist motive of exploration, most university administrators view research as an opportunity to supplement a declining revenue stream. These viewpoints need not be diametrically opposed.

Lean Six Sigma methodologies can be utilized as a cultural change mechanism to support faculty research, while simultaneously addressing the revenue enhancement issue. Consider how the following Lean Six Sigma perspectives can leverage faculty talent resources for the overall benefit of the university:

- Innovations in science and engineering require replication, the ability to duplicate results to determine applicability and accuracy. Lean Six Sigma processes can enable science and engineering researchers to determine variations and lower error rates in laboratory experiments to assist in the replication process.
- From the revenue enhancement perspective, research must generate ideas and technology that are useful to businesses and individuals outside the university. Lean Six Sigma processes can facilitate the external "customer" philosophy to drive research initiatives to problem solving. The establishment of research focus groups could allow the faculty resource to be leveraged to research and design solutions to practical problems faced by outside business and industry. In this manner, the university is seen as a process improvement arm of external entities to apply Lean Six Sigma techniques. The Lean process applied here will blur the lines between the external customer and the university, making problem solving/process improvement the higher goal above either entity's individual motivations.
- Likewise, Lean Six Sigma methodologies can be utilized to purpose faculty research abilities to governmental initiatives. Viewing the government as a "customer" in need of specific research capabilities brings the opportunity to jointly apply Lean Six Sigma to design methodologies and allocate faculty research resources for the benefit of both organizations.
- For the university research function to succeed over the long-term, Lean Six Sigma processes must be applied to the internal resource allocation issue. Specifically, faculty members who have research interest and aptitude must see that those talents are weighed and valued in the promotion and reward structure. Reiterating an earlier point, Lean Six Sigma methodologies should be applied to develop a matrix for faculty time allocation that would recognize the individual gifts of each faculty member and ensure a promotion and tenure pathway based on those talents.

Challenges and university culture

Adopting Lean Six Sigma as an institutional philosophy is not without challenges. First, few institutions openly identify their students as "customers". The resistance to using the customer label is ubiquitous in the higher education world, primarily due to the fact that institutions perceive the relationship with students to be much more complicated and deeper (Sirvanci, 1996; Quinn *et al.*, 2009). Still there seems to be an attitude of parochialism surrounding the "needs" of the student. Regardless of labels (student or customer), every institution desires to attract and retain them. If focused honestly on this goal, the culture of process improvement can be achieved.

Some authors have noted the existence of "shared governance" as a formidable obstacle to implementing process improvement methodologies (Ho and Wearn, 1995; Quinn *et al.*, 2009). Ironically, it is the premise of collaboration and shared responsibility that makes Lean Six Sigma a successful strategy for meaningful improvement. Thus, it may be argued that the higher education environment is best-suited for Lean Six Sigma, given the emphasis on shared governance. The key to successful implementation within the university environment is the avoidance of a top-down-driven process, focusing instead on the engagement of faculty in the design and implementation of the Lean Six Sigma methodology.

Conclusion

Lean Six Sigma, having been adopted by a host of businesses in the private sector, is capable of facilitating vast improvements in higher education. The processes and techniques comprising the Lean Six Sigma methodology can serve as the catalyst to bring about the meaningful change needed to ensure the continued relevance of universities in our evolving societal structure. The statistical techniques and resource allocation strategies of Lean Six Sigma can be effectively applied to the admissions, enrollment management, business and research functions to make higher education institutions more effective in identifying and addressing customer needs. Finally, while the implementation of Lean Six Sigma is not without obstacles and challenges, it can serve as an agent of cultural change for both public and private institutions.

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