Improving the admission process in a higher education institute using Lean Six Sigma: A case study

Author(s): Shamsuzzaman, Mohammad; Khadem, Mohammad; Haridy, Salah; Shamsuzzoha, Ahm; Abdalla, Mohammad; Al-Hanini, Marwan; Almheiri, Hamdan; Masadeh, Omar

Title: Improving the admission process in a higher education institute using Lean Six Sigma: A case study

Year: 2023

Version: Accepted manuscript

Please cite the original version:

Shamsuzzaman, M., Khadem, M., Haridy, S., Shamsuzzoha, A., Abdalla, M., Al-Hanini, M., Almheiri, H. & Masadeh, O. (2023). Improving the admission process in a higher education institute using Lean Six Sigma: A case study. *International Journal of Lean Six Sigma,* 15(7), 1596-1625. https://doi.org/10.1108/IJLSS-05-2021-0098

Improving the admission process in a higher educational institute using Lean Six Sigma: a case study

*Mohammad Shamsuzzaman (**Corresponding author**)
Department of Industrial Engineering and Engineering Management,
College of Engineering,
University of Sharjah,
United Arab Emirates
Email: mshamsuzzaman@sharjah.ac.ae
Phone: +971-6-5053974
Fax: +971-6-5053963
Email: mshamsuzzaman@sharjah.ac.ae
ORCID: https://orcid.org/0000-0002-1242-9627

Mohammad Khadem
Department of Industrial Engineering and Engineering Management,
College of Engineering,
University of Sharjah,
United Arab Emirates,
Email: mkhadem@sharjah.ac.ae

Salah Haridy
Department of Industrial Engineering and Engineering Management,
College of Engineering,
University of Sharjah,
United Arab Emirates,
Mechanical Engineering Department,
Benha Faculty of Engineering, Benha University, Benha, Egypt
Email: sharidy@sharjah.ac.ae

Ahm Shamsuzzoha
Digital Economy Research Platform
School of Technology and Innovations,
University of Vaasa,
Vaasa 65101, Finland
Email: ahm.shamsuzzoha@uwasa.fi

Mohammad Abdalla
Department of Industrial Engineering and Engineering Management,
College of Engineering,
University of Sharjah,
United Arab Emirates,
Email: u15101064@sharjah.ac.ae

Marwan Al-Hanini

Department of Industrial Engineering and Engineering Management,
College of Engineering,
University of Sharjah,
United Arab Emirates,
Email: u15102443@sharjah.ac.ae

Hamdan Almheiri
Department of Industrial Engineering and Engineering Management,
College of Engineering,
University of Sharjah,
United Arab Emirates,
Email: u15104461@sharjah.ac.ae

Omar Masadeh
Department of Industrial Engineering and Engineering Management,
College of Engineering,
University of Sharjah,
United Arab Emirates,
Email: u15101063@sharjah.ac.ae

Abstract:

Purpose – The purpose of this study is to implement Lean Six Sigma (LSS) methodology for improving the admission process by reducing admission cycle time in a Higher Educational Institute (HEI).
Design/methodology/approach – In this study, a case study research methodology is adopted and implemented through a LSS DMAIC (Define-Measure-Analyze-Improve-Control) framework.
Findings – The preliminary investigation showed that the completion of the whole admission process of a new student takes an average of 88 minutes, which is equivalent to a sigma level of about 0.71 based on the targeted admission cycle time of 60 minutes. The implementation of the proposed LSS approach increased the sigma level from 0.71 to 2.57, which indicates a reduction in the mean admission cycle time by around 55%. This substantial improvement is expected not only to provide an efficient admission process, but also to enhance the satisfaction of the students and employees and increase the reputation of the HEI to a significant level.
Research limitations/implications – In this study, the sample size used in the analysis is considered small. In addition, the effectiveness of the proposed approach is investigated using a discrete event simulation with a single case study, which may limit the generalization of the results.
Practical implications – This study uses several statistical process control tools and techniques through a LSS DMAIC framework to identify and resolve the root causes of long admission cycle time at a HEI. The approach followed, and the lessons learned, as documented in the study, can be of a great benefit in improving different sectors of the HEIs.
Originality/Value – This study is one of the few attempts in implementing LSS in HEIs for improving administrative process so that better-quality services can be provided to its customers such as students and guardians. The project is implemented by a group of undergraduate students as a part of their Senior Design Project, which paves the way for involving students in future LSS projects in HEIs. This study is expected to help improving the understanding of how LSS

methodology can be implemented in solving quality related problems in HEIs and to offer valuable insights for both academics and practitioners.

Keywords Service excellence, Lean Six Sigma, Higher Educational Institute, Administrative process, Admission process.

1. Introduction

Education is considered as one of the fundamental factors of economic and social development of any nation, and Higher Education (HE) plays a key role in this respect. Higher Educational Institutes (HEIs) including colleges and universities are complex organizations comprising of several academic and administrative processes. Academic processes include classroom teaching, examination, grading, student advising, curriculum design, faculty research productivity, student's feedback, and so on. On the other hand, administrative processes support the operations of the institutions including student's admission and registration, faculty recruitment, finance, payroll, and maintenance (Holmes et al., 2015). Even though the primary focus of a HEI is on academic processes, the business processes at administrative facilities significantly support and affect the performance of any academic institution. Because of the increasing number of population and technological advancement throughout the globe, there is a big hike in the number of students in any country. Besides, HEIs are always under increasing pressure to provide better services to satisfy their stakeholders and customers including students, industry partners, faculties, and researchers due to the requirements of global ranking of HEIs and accreditation process, and growing needs for highly skilled human resources and external funding amongst others (Svensson et al., 2015). In such a competitive environment, only institutions that provide high quality education, and supportive and attractive environment to their students can survive (Elliott & Shin, 2002; Butt & Rehman, 2010; Dharmayanti, Semuel, & Devie, 2018). As a result, student's satisfaction becomes a first priority and paramount importance for HEIs to retain existing students, increase enrollments, and attract new students (Gibson, 2010; Dharmayanti, Semuel, & Devie, 2018). Research (for instance, see Kotler & Fox, 1995; Mahmood, Dangi, & Ali, 2014; Iruloh & Ugwu, 2017) shows that students in majority of the HEIs are generally satisfied with the academic processes but less satisfied with supporting facilities and amenities such as admission and registration, career counseling, recreation, transportation, accommodation, dinning, and campus safety. For instance, Oko & Kang (2015) conducted a survey in Nigerian HEIs and found that 85% of the respondents are dissatisfied with the admission process. Therefore, the HEIs are strongly required to deploy continuous improvement initiatives to improve the administrative processes such as admission and registration. The student focus in a HEI is analogous to the customer focus in a manufacturing or other service sectors, and thus, the continuous process improvement methodologies such as LSS is equally applicable for process improvement in HEIs (Hess & Benjamin, 2015).

The first business processes a student needs to follow in any educational institute is the admission process. In most of the HEIs, the admission process needs support from several other departments such as admission, registration, finance and Information Technology (IT), and the total time required to complete the whole process is sometimes unexpectedly longer. This creates dissatisfaction among the students. Even though the nature and functionality of HEIs are quite different from manufacturing and other service organizations, it is believed that there is a great opportunity to deploy LSS in improving business processes in HEIs (Vijaya Sunder &

Mahalingam, 2018). As LSS has a significant impact on business process improvement and customer satisfaction (Thomas et al., 2016; Shamsuzzaman et al., 2018), this study is dedicated to apply LSS to reduce the cycle time of the admission process in a HEI, which in turn reduces the waiting time of the new students in the system, lowers the workload on the employees, increases student overall satisfaction, and improves the reputation of the institute. Therefore, the key research question handled in this study is how to improve the admission and registration processes at HEIs using LSS methodologies.

The structure of this paper is organized as follows: Section 2 provides a comprehensive review of the research on the application of LSS methodology in HEIs. Section 3 discusses the research methodology and the framework of LSS project implementation. Section 4 gives a brief explanation about the background of the case organization, and Section 5 discusses the results obtained from the case study. Section 6 shows the research implications and lessons learned from the study. Finally, Section 7 draws conclusions and suggests future research direction.

2. Literature review

Lean, Six Sigma (SS) and LSS are popular business process improvement strategies widely used to promote business and operational excellence. Lean aims to speed up and increases the efficiency of processes by eliminating the waste and non-value-added (NVA) activities across the organization, whereas SS targets improving organization's effectiveness by reducing process variation and defects from the design to the development stage throughout the product lifecycle. LSS is a synergy between Lean and SS that seeks to enhance business performance, ensure the effectiveness and efficiency of the processes, and therefore increase the customer satisfaction? and profitability (Alblooshi et al., 2020). Even though LSS has widespread applications in manufacturing, its application in service organizations, especially in HEIs is still growing (Antony et al., 2012; Antony, 2014).

Some researchers investigated the role of Lean, SS, or LSS to improve academic or administrative processes in HEIs. Specially, Lean has been widely used by some HEIs at the global level to improve academic or administrative processes and meet demands of HE marketplace (Antony, 2017). For example, Emiliani (2004) and Dey (2007) used Lean principles and practices in developing and delivering a graduate business course curriculum at a management institute to improve the learning process of the students. Similarly, El-Sayed et al. (2011) applied Lean principles in developing student's assessment process to address quality and continuous improvement issues in HE. In the same aspect, Sinha & Mishra (2013) explained how Lean concept can be implemented in course review process by building and analyzing process maps, identifying the value added and NVA activities, and discussing the role of faculty, student, and industry. Waterbury (2015) further highlighted the common challenges faced and lessons learned when implementing Lean in HEIs, whereas Douglas et al. (2015) identified eight types of wastes from Lean perspective and suggested the appropriate solutions to those wastes in the context of HEIs. Balzer et al. (2016) reviewed sixty-four articles from the year 2000 to 2015 with reference to Lean in HE. They divided their review into two categories such as Lean implementation at a department/unit level, and throughout an institution level. The results of their study revealed that Lean can successfully lead to a significant and measurable improvement when used to improve academic and administration processes at HEIs.

SS is another proven strategy for improving organization's effectiveness and achieving higher levels of performance. Goffnett (2004) discussed the adaptability of SS in industry and

academia. Hoerl & Bryce (2004) explained the issues needed to be addressed in implementing SS in academia to get full advantages of what SS offers, whereas Jenicke et al. (2008) and Holmes et al. (2005) discussed the relevancy, challenges, and anticipated benefits of implementing SS philosophy in an academic setting. Burtner (2004) identified several potential SS projects at Mercer University and highlighted that a good SS project can provide university administration with the necessary data and information to make effective changes in the academic programs? and policies. Box (2006) went one step further to conduct a learning experiment in redesigning a management course following SS concepts and explained the benefit achieved by the implementation of such SS project. Kumi & Morrow (2006) implemented SS methodology to improve self-service process at Newcastle University library and suggested to develop a fault reporting system to control the length of time a unit was out of order and to reduce the number of times the faults occurred. Jenicke et al. (2013) proposed a conceptual model of a hierarchical approach in which SS methodology was used to improve undergraduate business student retention. Ramanan et al. (2014) & Vijaya Sunder (2014) proposed deploying an SS DMAIC framework to positively impact quality of education in a HEI and discussed how student teams can be involved in the proposed frameworks. A cost-effective project selection is an important step in any SS implementation. Holmes et al. (2014) proposed a framework for SS project selection based on weighted scorecard and demonstrated its application in Midwestern University for improving help desk process. Likewise, Laux et al. (2017) discussed a conceptual framework incorporating SS DMAIC methodology and big data analytics to improve student success rate at a US public university. Ongy (2016) used SS DMAIC methodology for improving enrollment process of undergraduate students at Visayas State University. The study designed descriptive research utilizing a survey method which showed that the root causes of the long enrollment processing time are mainly due to lack of capacity of assessment and printing facilities.

Even though the integrated LSS methodology has been implemented extensively in the manufacturing sectors, the application of LSS, specially from practical viewpoint, is still growing in service sectors, particularly in HEIs. Some researchers discussed the underlying challenges, obstacles and the critical success factors for the introduction and implementation of LSS in HEIs (Antony et al., 2012; Antony, 2015; Antony & Cudney, 2016). However, before implementing LSS framework, its readiness for deployment in any organization is crucial. Antony (2014) introduced the readiness factors (RFs), which he believes are crucial pre-requisites for the successful introduction and implementation of LSS in HEIs. Based on existing literature, the study (Antony, 2014) identified five RFs such as leadership and vision, management commitment and resources, linking LSS to university's strategy, customer focus and selecting the right people. These RFs can be used by HEIs prior to embarking on the LSS journey to ensure a sustainable implementation. Similarly, Vijay Sunder & Antony (2018) proposed a six-staged conceptual framework for HEIs application. The authors emphasized that before establishing LSS framework in an organization, the LSS readiness is prerequisite for the organization. This framework is consisted of establishing leadership need, developing a strategy, educating students with right skill set, team formation, identifying and initiating LSS projects, and finally, the review and closure phases. Wiegel & Hadzialic (2015) argued that education and other domains are structurally different and currently LSS is not fully fit to take into account these differences. Based on six variables describing structural differences, Wiegel & Hadzialic (2015) developed a framework that can be efficiently used to establish initial assessments of the fitness of LSS for HEIs. Anthony & Antony (2017) analyzed the maturity level of the UK universities when implementing LSS and compared the results with the findings from international universities. Based on the data collected

form 21 UK universities and 17 international universities, Anthony & Antony (2017) concluded that the UK universities suffer from dearth of maturity in implementing Lean/SS/LSS methodologies and expected that the UK will mature over time. Furthermore, Antony *et al*. (2018) conducted studies to identify the challenges and key success factors in developing LSS program in UK HEIs, and focused on some LSS projects executed at administrative, human resources, finance, library, and IT sectors of the university. The study identified several factors for successful implementation of LSS projects in HEIs such as visionary leadership, organizational readiness and culture, project prioritization, and effective communication. Likewise, Lu *et al.* (2017) proposed a theoretical model for LSS leadership using an inductive theory-building approach. This model showed a potential to support in improving the quality of education, reducing the NVA costs and boosting the operational efficiency of HEIs. The study emphasized that the LSS leadership is vital to overcome critical issues and challenges in the HEIs.

Because of joint features of Lean and SS, many researchers implemented the LSS methodology in HEIs. Hess & Benjamin (2015) reviewed historical development of LSS in the past three decades and discussed how LSS can be applied in universities to improve processes in curriculum delivery, business and auxiliary services, admissions and enrolment management, and research. Svensson et al. (2015) discussed how LSS was introduced and rolled out in King Abdullah University of Science and Technology (KAUST) in Saudi Arabia. The program in KAUST was launched in 2011 in streamlining support functions to initiate process improvements that will benefit students, faculty, and staff. The study mainly focused on the training of the workforce at different levels of the university and provided a simple example of implementing LSS in administrative process for improving the onboarding process of the new international students. Oko & Kang (2015) applied LSS DMAIC methodology to improve the admission process in the ELITE state polytechnic by conducting a qualitative research analysis, where the data were collected from questionnaire survey.

Vijay Sunder (2016) discussed the key components of employing LSS in HEIs compared with those in manufacturing industry. The study then used LSS DMAIC methodology to improve the university library system by reducing book search time through webpages on internet. Thomas *et al.* (2017) proposed an integrated LSS framework to be implemented in academic setting and discussed its application in the curriculum design and delivery of a new undergraduate engineering program. Gupta et al. (2018) investigated potential causes of student dropouts in HEIs and explored the possible use of LSS tools in reducing the dropout rate. They conducted qualitative research by interviewing nine university employees to understand the dropout phenomenon. They also interviewed three LSS experts to understand how LSS can be used as a tool to tackle this issue, and finally, a DMAIC based methodology is developed by the experts for reducing the dropout using LSS.

Vijaya Sunder & Mahalingam (2018) recognized the recent interest in implementing LSS in HEIs and set out to examine its hype using multiple case-study method in two university colleges. The first case study focused on improving the utilization of the central library, whereas the second case study focused on increasing the customer satisfaction in the university computer center. Li et al. (2019) implemented LSS principles to support the creation of quality grant proposals and contracts for staff at Purdue Sponsored Program Services Pre-Award office and explained how the potential benefits such as reduced service lead-time, lower work-in-process inventory and improvement on imbalanced workflow could be achieved through the execution of the LSS project. Haerizadeh & Vijaya Sunder (2019) provided a case study that was conducted in a reputed university in Iran. The authors used LSS DMAIC framework for improving the student

satisfaction by reducing student's services and advising waiting time. Nadeau (2017) and Cudney et al. (2020) provided systematic literature reviews to identify opportunities for the implementation of Lean, SS, and LSS in improving quality in HE based on existing literature and concluded that such approaches are still quite novel in academia and yet to be introduced into the university system as a whole.

The types of applications and the methodologies employed in the above-mentioned articles are summarized in Table 1. As shown in Table 1, a considerable number of theoretical research has been devoted to find the ways of implementing LSS in HEIs. However, very few articles focused on the application of LSS for improving administrative processes at HEIs, and the articles that handled admission and registration processes used either only SS tools and/or qualitative research. Consequently, there is an urgent need for conducting further research on the practical application of LSS methodology for improving admission processes in HEIs using both qualitative and quantitative methods to draw meaningful conclusions.

Table 1. Types of applications and methodologies considered in LSS literature in HEIs

Methodology employed	**Reference**	**Practical application in HEIs**		**Theoretical explanation of potential use in HEIs**
		Academic process	**Administrative process**	
Lean	Waterbury (2015), Douglas et al. (2015), Balzer et al. (2016)			√
	Emiliani (2004), Dey (2007), El-Sayed (2011), Sinha and Mishra (2013)	√		
Six Sigma (SS)	Hoerl & Bryce (2004), Goffnett (2004), Burtner (2004), Holmes et al. (2005), Jenicke et al. (2008), Vijaya Sunder (2014), Ramanan et al. (2014), Laux et al. (2017)			√
	Box (2006), Jenicke et al. (2013)	√		
	Kumi & Morrow (2006), Holmes et al. (2015), Ongy (2016)		√	
Lean Six Sigma (LSS)	Antony et al. (2012), Antony (2014), Antony (2015), Hess & Benjamin (2015), Wiegel & Hadzialic (2015), Antony & Cudney (2016), Anthony & Antony (2017), Lu *et al.* (2017), Antony et al. (2018), Vijay Sunder & Antony (2018), Cudney et al. (2020)			√
	Svensson et al. (2015), Oko & Kang (2015), Vijay Sunder (2016), Vijaya Sunder & Mahalingam (2018), Haerizadeh & Vijaya Sunder (2019), Li et al. (2019)		√	
	Thomas et al. (2017), Gupta et al. (2018)	√		

3. Research methodology and implementation framework

Yin (2009) defines a case study as a pragmatic enquiry that examines a contemporary phenomenon within its real-life setting using multiple sources of evidence. A case study generally does not focus on entire organization, instead it focuses on a particular issue, feature, or unit of analysis (Noor, 2008). In addition, case study is an appropriate research method that helps in gaining solid, circumstantial, and comprehensive knowledge about a specific real-world problem. Thus, we use a case study research methodology to understand, investigate and provide effective solution for minimizing the admission cycle time at a HEI. Even though a single case study is recognized as a valid research methodology (Woodside, 2010), the results obtained from a single case study usually suffer from generalization problem. However, Yin (2009) clarified that the case studies could be generalized to theoretical propositions and not to populations or universally.

In this study, both qualitative and quantitative data are collected from multiple sources. Qualitative data is obtained from interviews with different personnel at different levels of the admission process. As there are no historical records available, some quantitative data are collected from direct observations of the process. The statistical analysis and graphical presentations of the results are accomplished using Minitab statistical software at 5% significance level. In addition, ARENA simulation software is used to develop a model to test the effectiveness of the proposed solution approaches under different scenarios. The LSS implementation framework followed in this study is demonstrated in Figure 1.

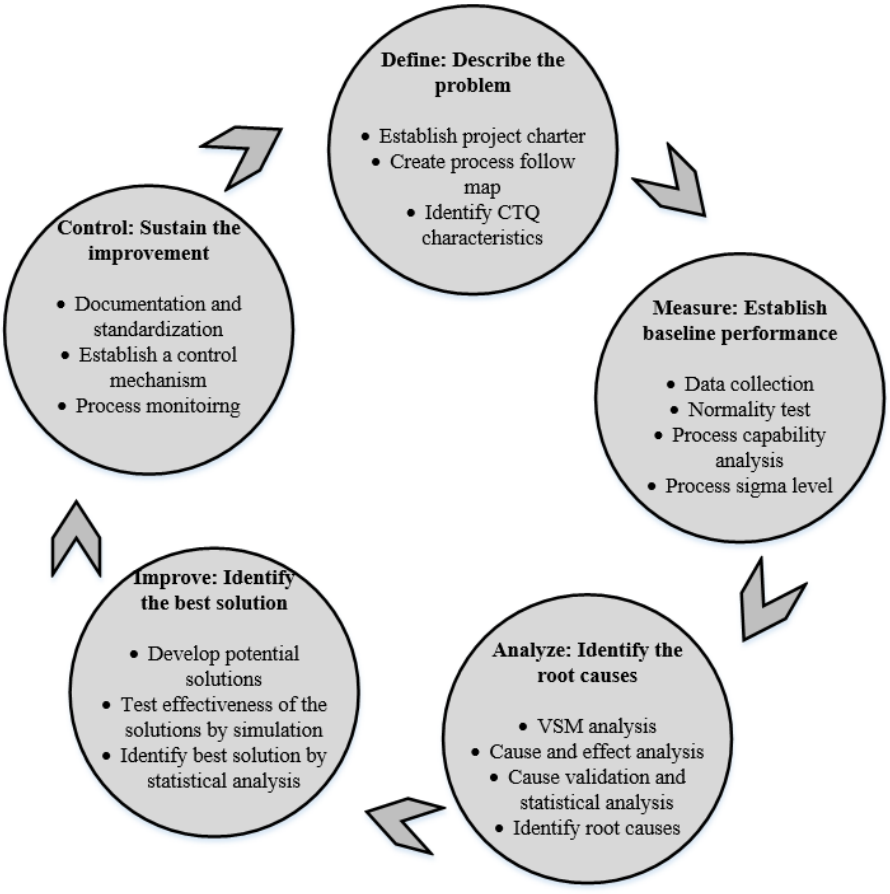

Figure 1. LSS project implementation framework

The proposed framework is an integrated approach of Lean and SS. It is based on the five phases of the DMAIC methodology. The first phase of the LSS implementation framework is the Define phase, which aims to set the project's goal, form an implementation team, develop a project charter, and identify the critical-to-quality (CTQ) characteristics. The second phase of the LSS project is the Measure phase in which the required data on the CTQ characteristics are collected, and the baseline performance level of the CTQ characteristics is determined. The third phase is the Analyze phase, which aims to identify the factors that influence the CTQ characteristics so that the root causes of any abnormal behavior of the CTQ characteristics can be identified. The fourth phase is the Improve phase, which aims to generate solution alternatives and test them for all root causes identified in the Analyze phase, and to implement the best solution idea in practice. The last phase of the LSS framework is the Control phase in which the whole process is documented, and a system is developed to ensure that the improvements made in the Improve phase is sustained over time. Several tools and techniques, such as Supplier-Input-Process-Output-Customer (SIPOC) diagram, process flow map, Value Stream Mapping (VSM), simulation, control chart, process capability analysis, and Gemba Walk are used throughout the DMAIC phases.

4. Case study

In this section, a brief explanation of the case organization and the implementation of the case study framework are presented, and the findings are discussed.

4.1 Case organization

The case organization in this LSS project is a HEI in the United Arab Emirates. Due to the good reputation of this HEI, it has an increasing number of enrolled students in each semester. With the increased number of enrolled students, it is noticed that the admission process for new students requires long time than expected. The waiting time in the queue is unexpectedly very long, which results in congested queue during some periods of time that leads to dissatisfaction among the students and guardians. Since several activities are required to be followed in the admission process, the causes of the long admission cycle time are apparently unknown and difficult to identify instantly. LSS is an approach that widely recommended to use in such a situation to identify the root causes of the problem (Psychogios et al., 2012; Thomas et al., 2016). It is noted that the case HEI has its own Quality Assurance (QA) department; however, the QA department mainly focuses on strategic planning, assessment, and accreditation activities. This is the first attempt to implement an LSS project in the case HEI to improve the admission process of the new students. It is worth mentioning that the LSS project proposed in this study is implemented by a group of undergraduate students as a part of their Senior Design Project. The involvement of the students provides a great opportunity for them to gain hands-on experience through implementing their academic knowledge in solving real-world problems.

4.2 Implementation of the case study framework

The framework shown in Figure 1 is followed in this section with the aim to improve the admission process. The project is implemented through the following five steps.

4.2.1 Define phase

The Define phase usually starts with identifying a problem that needs a solution and ends with an understanding of the scope of the problem. In this project, the objective is to reduce the total time required to complete the admission process for the new students. A project implementation team was formed including an academician, four undergraduate students, different personnel at various managerial levels of the relevant departments such as Admission, Finance, Registration, and IT. In any LSS project, the construction of a project charter is an important step as it provides a brief description of the whole project including objective, scope, and expected benefit to the case organization (see Figure 2).

Background and reasons for selecting the project	**The preliminary investigation showed that the completion of the whole admission process of a new student takes an average of 88 minutes, and in some cases, it takes even 2 hours or longer. This results in dissatisfaction among the students and guardians.**				
Scope of the project	The scope of the project is to identify and eliminate the root causes of the long admission cycle time so that the time required to complete the admission process of the new students is minimized.				
Not included in the scope	The time required to get initial acceptance through online application and time required to complete the placement test of the new students are not considered in the calculation of the admission cycle time. Cost/benefit analysis of the project is also beyond the scope of the study.				
Goal of the project	To reduce the new student's overall admission cycle time from 88 minutes to 60 minutes or less.				
Team members	An academician, four SDP students, concerned personnel of the Admission, Finance and Registration departments of the case Institute.				
Expected benefit	Lowering the admission cycle time will reduce the stress and workload on the employees and make the process faster and easier to go through, which in turn will increase the satisfaction of the students and guardians and improve the reputation of the HEI.				
Project plan	Define	Measure	Analyze	Improve	Control
	3 Weeks	3 Weeks	4 Weeks	4 Weeks	1 Week

Figure 2. Project charter

After creating the project charter, a SIPOC diagram (Figure 3) and a detailed process flow map (Figure 4) were developed by investigating the steps the students need to follow to complete the admission process. A SIPOC diagram and a process flow map help to define the scope of the study and to identify all stakeholders, process steps, inputs/outputs, and suppliers/customers of the process.

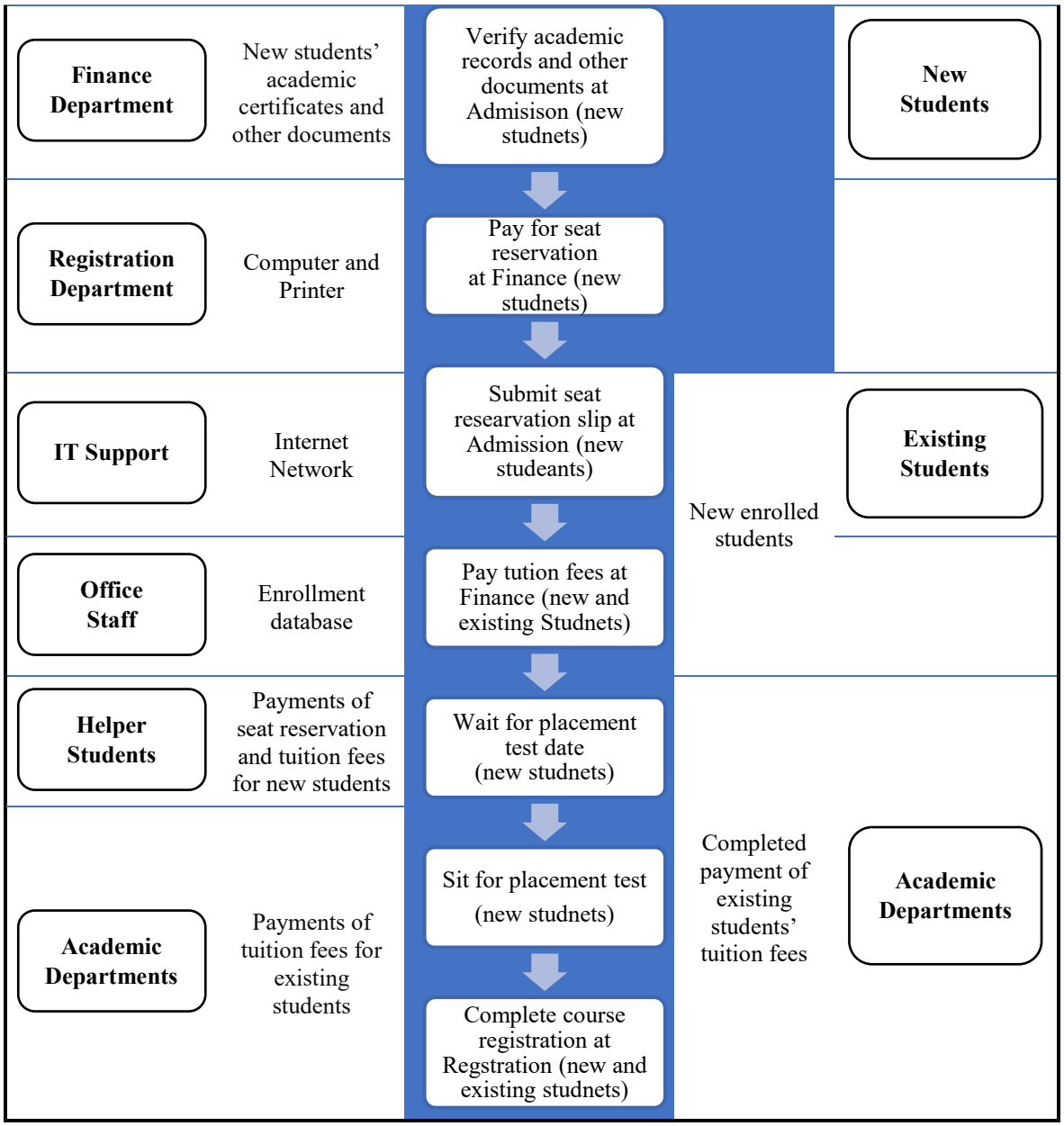

Figure 3. SIPOC diagram of the admission process of the case HEI

The admission process starts when a new student enters the website of the case HEI and applies online for a major. The new students need to complete the online form with necessary information to get initial acceptance to the case HEI. After submitting the online application and getting acceptance, the students need to come to the case HEI to submit all academic and other required documents in the Admission department for verification and record. Then, they move to Finance department to pay for seat reservation fees. After paying seat reservation fees, they comeback to Admission department to submit the payment slip, and after getting clearance from the Admission department, they need to move to Finance department again to complete the payments for tuition fees. After paying tuition fees, students usually leave the case HEI and wait

for the placement test. When the placement test results are published, the student comes back to the case HEI to complete the course registration in the Registration department. The admission cycle is over after completing the course registration step. In this study, the online application and placement test steps are excluded in this study while measuring the admission cycle time as they are external activities and difficult to monitor and control. It is noteworthy that the numbers of full-time employees serve the students at Admission, Finance and Registration departments are currently 3, 2, and 2, respectively. The departments are operational every day from 8:00 AM to 3:00 PM over 5 days a week. The process flow map to be investigated in this study is shown in Figure 4.

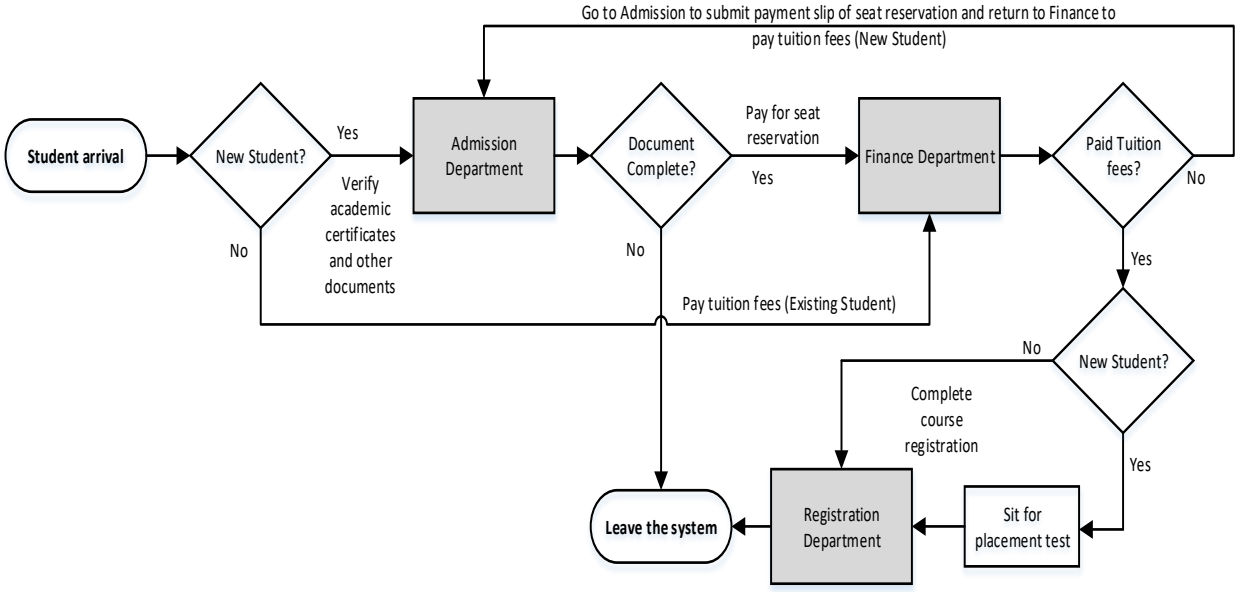

Figure 4. Admission process flow map

The CTQ characteristic is defined as the "admission cycle time", which is the total time required by a new student to complete the admission process and is defined as the time since the student submits the official documents in the Admission department until the student gets the course schedule from the Registration department. Based on the discussion with the concerned personnel of the Admission, Finance and Registration departments, the project implementation team defined the Upper Specification Limit (USL) of the CTQ characteristic as 60 minutes. Thus, the admission cycle time of any student that exceeds 60 minutes is considered as a defect.

4.2.2 Measure phase

The purpose of this phase is to evaluate the present status of the CTQ characteristic in terms of sigma level. The sigma level provides a high-level baseline to understand the capability of a process to meet customer requirements. For this purpose, data on admission cycle time was collected. As mentioned earlier, every student needs to go thru three major steps such as submitting admission related documents to Admission department, making payments to Finance department, and registering courses in Registration department to complete the cycle (see Figure 4). In each department, every student is supposed to collect a ticket from electronic kiosk machine and wait in the queue for his/her turn. The service starting and ending times for each student are also

recorded in the computer system. With the help of IT department, the project team members (four Senior Design Project students) collected data on ticket collection time (student arrival time), service starting and ending times for 50 students, and finally, the cycle times for each of the 50 students were calculated. It is noted that the data were collected randomly at different times and days over the semester. It is also noted that the data collection process only considered the undergraduate students and did not distinguish between the national and international students as all undergraduate students need to go thru the same admission process.

In order to measure the baseline performance of the process in terms of sigma level, the data on CTQ characteristic (i.e., the admission cycle time) were first checked for normality using normal probability plot (Figure 5), which confirms that the data follows normal distribution (P-value = 0.052). The data were then used to draw a Shewhart individual control chart for variable (Montgomery, 2019) to ensure that the data has only natural variability (i.e. the process is statistically in-control). After excluding eight out-of-control sample points in the second iteration, all sample points fell within the control limits of the individual control chart, which ensures that the process is in control (see Figure 6). The in-control data were then used to conduct process capability analysis as shown in Figure 7 using a USL of 60 minutes as mentioned before. It was found that the overall PPM (non-conforming Parts Per Million) value of the process is 784040. Finally, based on the PPM value, the sigma level of the process was found to be 0.71, assuming a 1.5 Sigma shift in the process mean (Pyzdek & Keller, 2014). The baseline performance of 0.71 Sigma level indicates that there is a room for further improvement in the admission process. It is also noted that the in-control mean and standard deviation of the current admission process (i.e., mean and standard deviation of the admission cycle time) are about 88.0 minutes and 34.2 minutes, respectively.

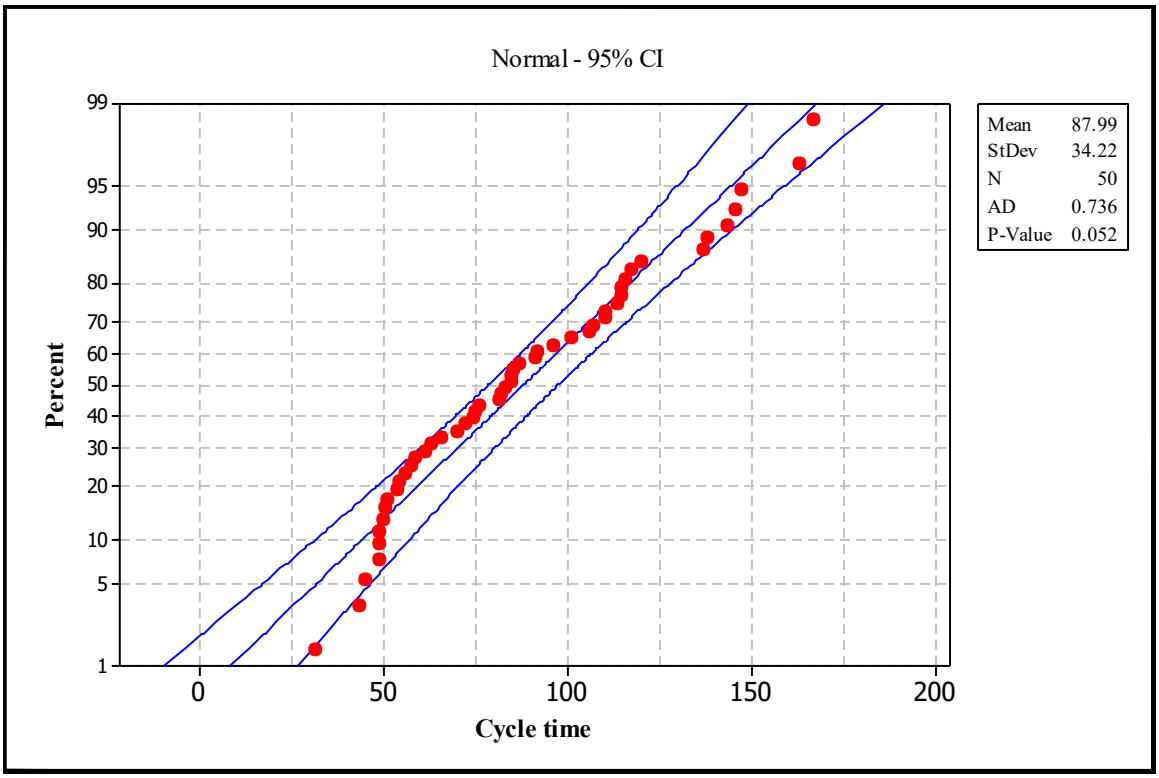

Figure 5. Normal probability plot of the admission cycle time data

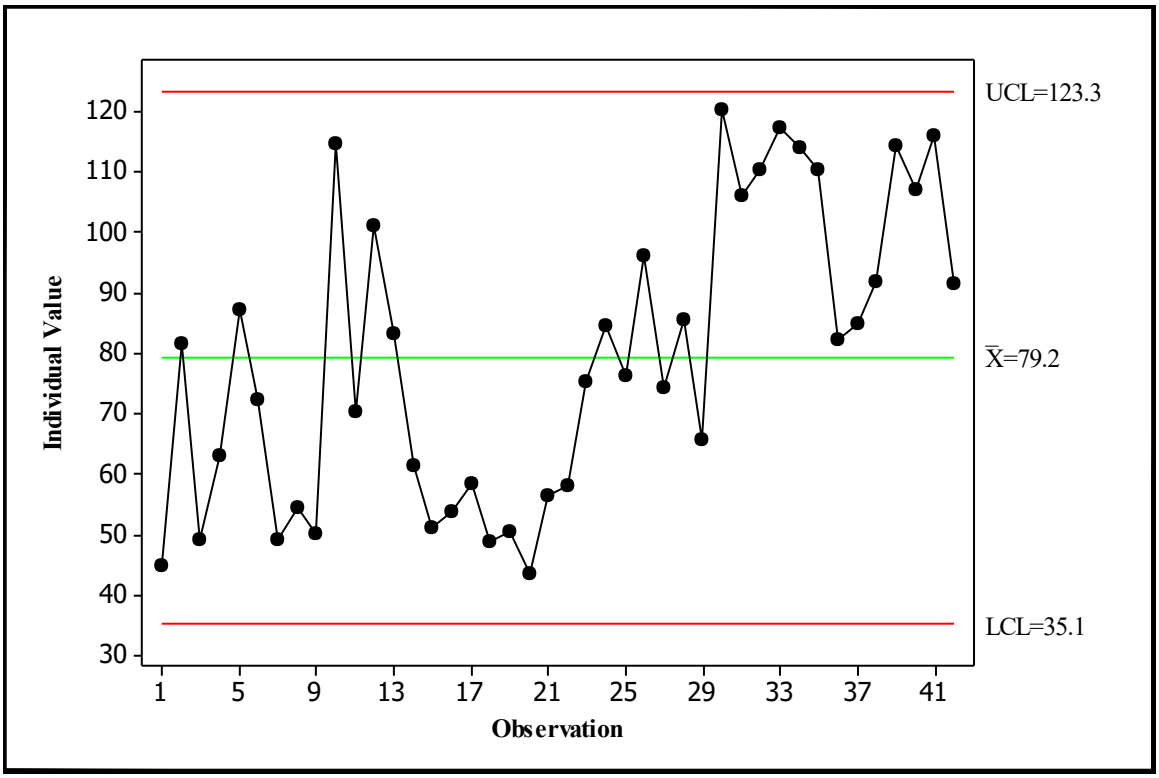

Figure 6. Shewhart individual control chart (in-control)

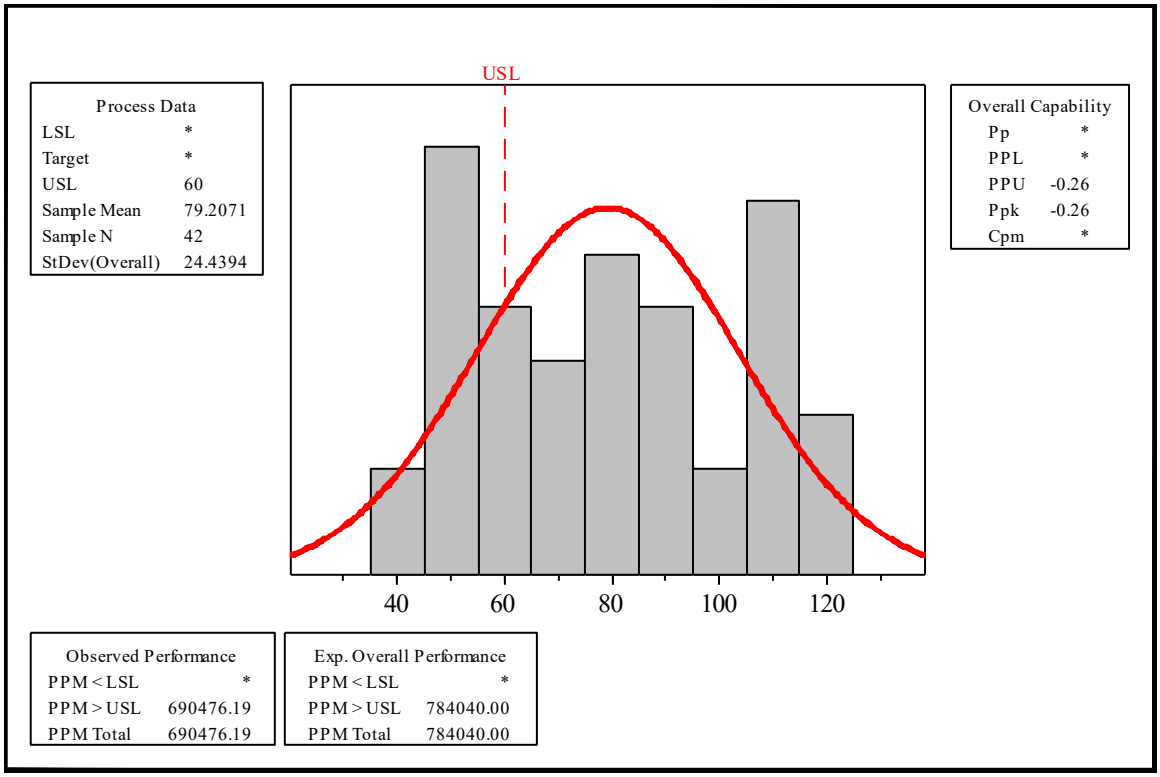

Figure 7. Process capability analysis of the admission cycle time data

4.2.3 Analyze phase

The factors that are responsible for the long admission cycle time are identified and the related causes are analyzed in the Analyze phase. The project team met the concerned personnel of the Admission, Finance and Registration departments and discussed about the related activities they need to follow to complete the task at each department. Based on the data collected in Measure phase on the average waiting and service times in each department, information collected from interviews with the concerned personnel and the process flow map, a VSM shown in Figure 8 was constructed to understand the procedure required to complete the process and to identify the NVA activities. From the current state of the VSM, it was deduced that 50.7 minutes (57.6% of the 88-minute cycle time) are actually NVA activities. While preparing the VSM, three types of wastes (NVAs) that belong to the current process were identified as follows:

- *Waiting time*: time that the students is not served. It starts from taking a ticket from the kiosk machine and ends when the service starts.
- *Over-processing*: it is defined as the unnecessary work done the operators (servers) than what the student requires.
- *Motion*: it is the repeated movement of the students throughout the admission process, especially because of more than one payment steps in the Finance department.

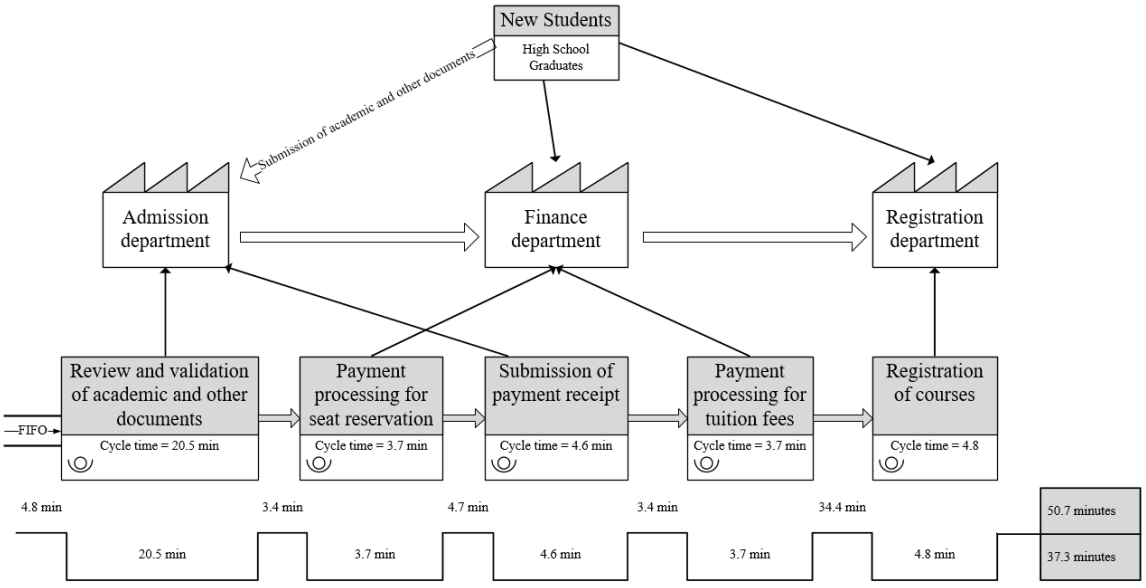

Figure 8. Value stream mapping of the admission process

In addition to the three types of NVAs, more brainstorming sessions were conducted to identify the potential causes of the long admission cycle time. All the main causes and corresponding sub-causes obtained from the brainstorming sessions and the NVAs identified using the VSM are presented in a cause-and-effect diagram as shown in Figure 9.

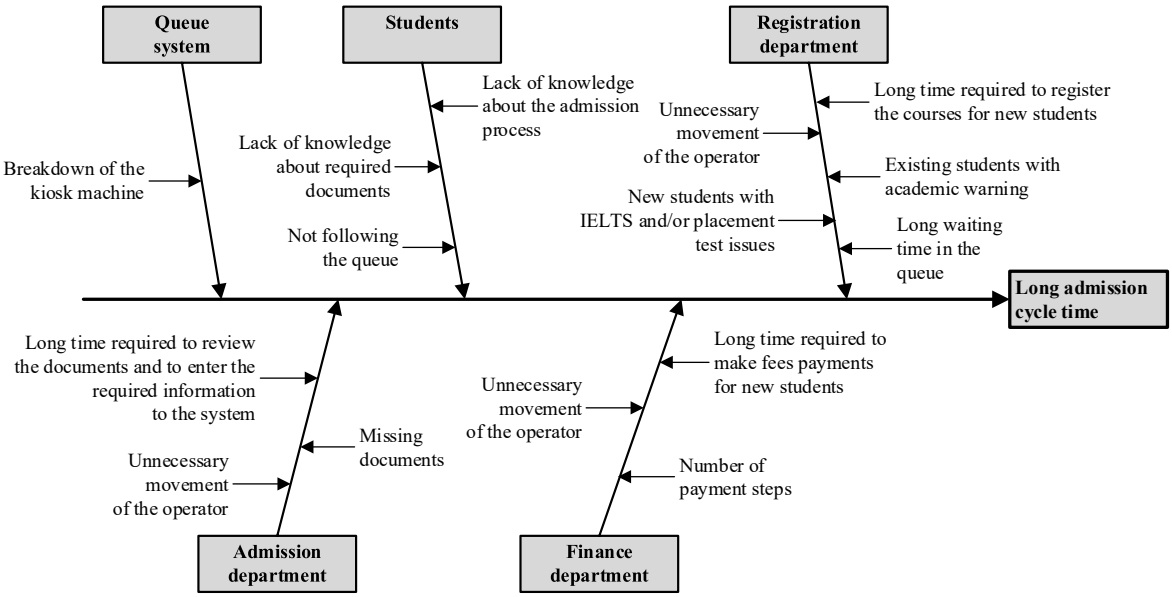

Figure 9. Cause and effect diagram for the long admission cycle time

All the 15 potential causes of the long admission cycle time identified in Figure (9) are initially investigated and analyzed by Gemba Walk (Womack, 2011) based on the following two criteria:

- The desired states or conditions of each cause.
- The frequency of each cause in a period of 3 weeks.

The results obtained from the Gemba Walk are summarized in Table 2.

Table 2. Results summary of Gemba Walk

No.	Potential causes	Desired states	Observation	Remark
1	Breakdown of the kiosk machine (Queue system).	The kiosk machine should have no problem on the workdays.	Observed rarely over 3 weeks.	Not root cause.
2	Lack of knowledge about the admission process (Students).	The new students (and/or guardians) should have clear idea about the steps of the admission process before starting the process.	Observed at least once, on daily basis on 2 weeks out of 3 weeks.	**Potential root cause.**
3	Lack of knowledge about the required documents (Students).	The new students (and/or guardians) should have clear idea about the necessary documents before starting the process.	Observed at least once, on daily basis on 2 weeks out of 3 weeks.	**Potential root cause.**
4	Not following the queue (Students).	The process should have smooth flow of the students (and/or guardians).	Observed rarely over 3 weeks.	Not root cause.
5	Long time required to register courses for new students (Registration department).	The registration of courses should be completed within a reasonable timeframe.	Observed at least three times over 3 weeks.	**Potential root cause.**
6	Unnecessary movement of the operator or server (Registration department).	The operators (servers) should concentrate on their job and minimize unnecessary movements specially because of personal requirements.	Observed rarely over 3 weeks.	Not root cause.
7	Existing students with academic warning (Registration department).	The existing students should not be allowed to affect the registration process of the new students.	Observed twice over 3 weeks.	Not root cause.

8	New students with IELTS and/or placement test issues (Registration department).	The new students with IELTS and/or placement test issues should get extra help in completing the course registration process.	Observed rarely over 3 weeks.	Not root cause.
9	Long waiting time in the queue (Registration department).	Waiting time in the queue should not be very long.	Waiting time is usually very long. Observed very frequently over 3 weeks.	**Potential root cause.**
10	Long time required to review the documents and to enter the required information to the system (Admission department).	The service time at Admission department should be minimum.	Usually takes long time. Observed very frequently over 3 weeks.	**Potential root cause.**
11	Missing documents (Admission department).	The students should provide all required documents during the admission process.	Observed at least once, on daily basis on 2 weeks out of 3 weeks.	**Potential root cause.**
12	Unnecessary movement of the operator or server (Admission department).	The operators (servers) should concentrate on their job and minimize unnecessary movements specially because of personal requirements.	Observed rarely over 3 weeks.	Not root cause.
13	Time to make fees payments for new students (Finance department).	The payment process should be completed within a reasonable timeframe.	Observed at least four times over 3 weeks.	**Potential root cause.**
14	Unnecessary movement of the operator or server (Finance department).	The operators (servers) should concentrate on their job and minimize unnecessary movements specially because of personal requirements.	Observed rarely over 3 weeks.	Not root cause.
15	Number of payment steps (Finance department).	The number of times the students (and/or guardians) need to visit the Finance department to complete all fees payments should be minimum.	All new students need to visit Finance twice to complete the payments.	**Potential root cause.**

As shown in Table 2, eight causes were initially identified as the potential root causes of the long admission cycle time. A survey was then conducted among the newly admitted students to get more insights and information about the eight potential root causes. The students were asked whether they faced any of those eight potential root causes based on a dichotomous scale (1-Yes, 0-No) during the admission process. Fifty-eight responses from 30 female and 28 male students were obtained. The Cronbach's alpha values of the data collected on the eight potential root causes were calculated, which confirmed that the collected data are reliable as all Cronbach's alpha values were larger than 0.70 (Nunnally, 1978). A Pareto chart was then constructed based on the collected data as shown in Figure 10.

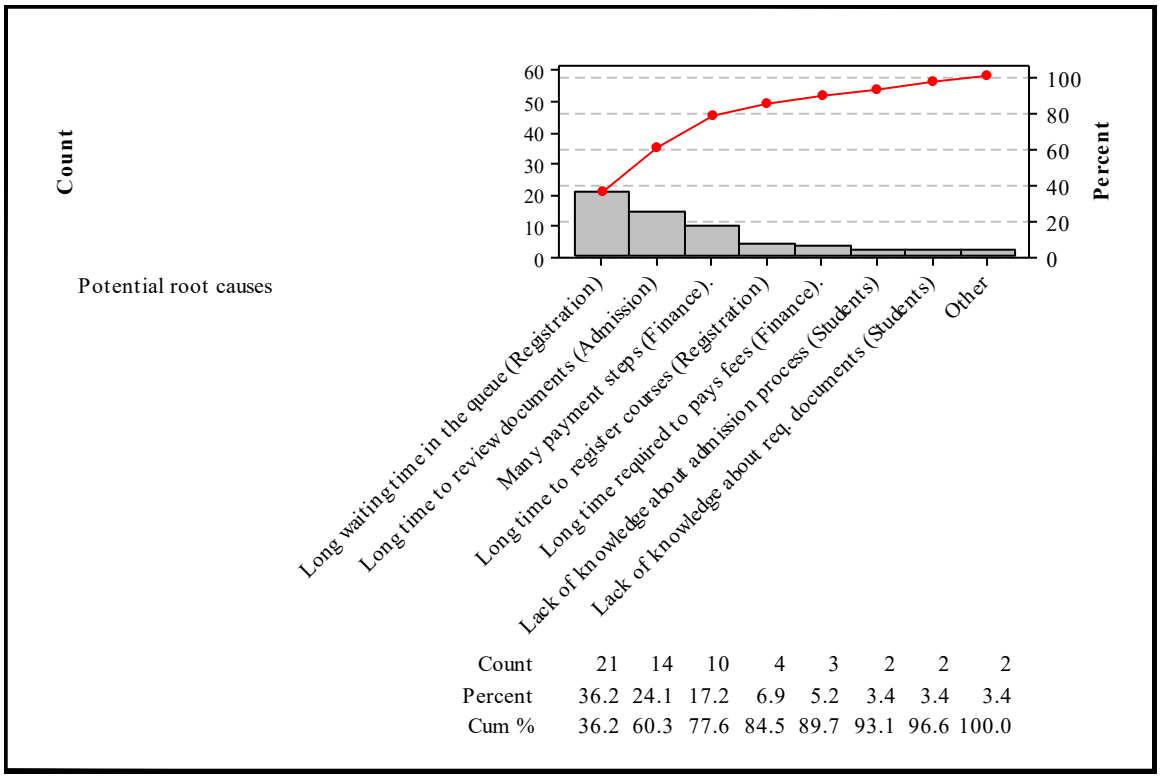

Figure 10. Prioritizing the potential root causes by Pareto principle

As shown in Figure 10, three potential root causes ("waiting time in the queue (Registration department)", "time required to review the documents and enter the required information to the system (Admission department)", and "number of payment steps (Finance department)" are representing about 78% of the causes and are mainly responsible for the long admission cycle time.

A factorial survey experiment (Antony, Sivanathan, & Gijo, 2014) was then conducted to validate and identify which of the three potential root causes has significant impact on the admission cycle time, where Registration ("waiting time in the queue"), Admission ("time required to review the documents and enter the required information to the system"), Finance ("number of payment steps") were considered as the input factors and the student's score on the expected admission cycle time was deemed as the response. This score was determined by the newly admitted students who recently went thru the admission process, based on a five-point scale (1-very low cycle time, 2-low cycle time, 3-medium cycle time, 4-high cycle time, and 5-very high cycle time). In the survey factorial experimental design, each of the three factors has two levels: high (+) and low (-) levels. The levels of each factor were decided based on the current statuses of the three potential root causes and discussions with the concerned employees of the three departments. Currently, the overall waiting time in the Registration is 34.4 ≈ 35 minutes, overall service time in the Admission is 20.5 ≈ 21 minutes, and number of payment steps in the Finance is 2. The low and high levels of the overall waiting time in the Registration and overall service time in the Admission were decided by adding ±10 minutes to the current overall values. On the other hand, the low and high levels of the payment steps in Finance were decided by adding ±1 to the current value. Table 3 shows the low and high levels of the three factors used in this study.

Table 3. Levels of the three factors

Factor	Low level (-)	High level (+)
Registration (“waiting time in the queue”, minutes),	25	45
Admission (“time required to review the documents and to enter the required information to the system”, minutes)	11	31
Finance (“number of payment steps”)	1	3

In each of the eight runs resulted from the 2^3 (= 8 different combination of the factors) survey factorial experiment, 10 randomly selected students (6 female and 4 male undergraduate students) were asked to assign score on the expected cycle time and the average score for each run was calculated. A statistical analysis was then conducted based on the average scores obtained from the survey to invetsigate the impact of the three factors (Regsitration, Admission, and Finance) on the response (admission cycle time). It is noted that the three-factor interaction effect is considered as a noise term in the analysis and used to estimate the sum of the squares of the error. The analysis, as shown in Figure 11(a), shows that the main factors such as Registration (P-value = 0.015), Admission (P-value = 0.028), and Finance (P-value = 0.049) have significant impacts on the admission cycle time at 5% significance level. However, none of the two-factor interaction effects is statistically significant. The main effect plot for each of the three factors is also shown in Figure 11(b), which shows that all the three factors have positive impact on the response. However, the effect of “Registration” on the admission cycle time is comparatively higher than other factors, that is, a slight increase in the Registration (i.e., waiting time in the queue) will increase the admission cycle time to a larger degree, and *vice versa*. Conversely, the factor “Finance” (i.e., number of payment steps) has the least impact on the admission cycle time. The three major root causes identified in this phase are taken into consideration in the Improve phase to find feasible and better solution to reduce the admission cycle time considerably.

Estimated Effects and Coefficients for Average score (coded units)

Term	Effect	Coef	SE Coef	T	P
Constant		3.9375	0.01250	315.00	0.002
Registration	1.0750	0.5375	0.01250	43.00	0.015
Admission	0.5750	0.2875	0.01250	23.00	0.028
Finance	0.3250	0.1625	0.01250	13.00	0.049
Registration*Admission	-0.2250	-0.1125	0.01250	-9.00	0.070
Registration*Finance	-0.0750	-0.0375	0.01250	-3.00	0.205
Admission*Finance	0.0250	0.0125	0.01250	1.00	0.500

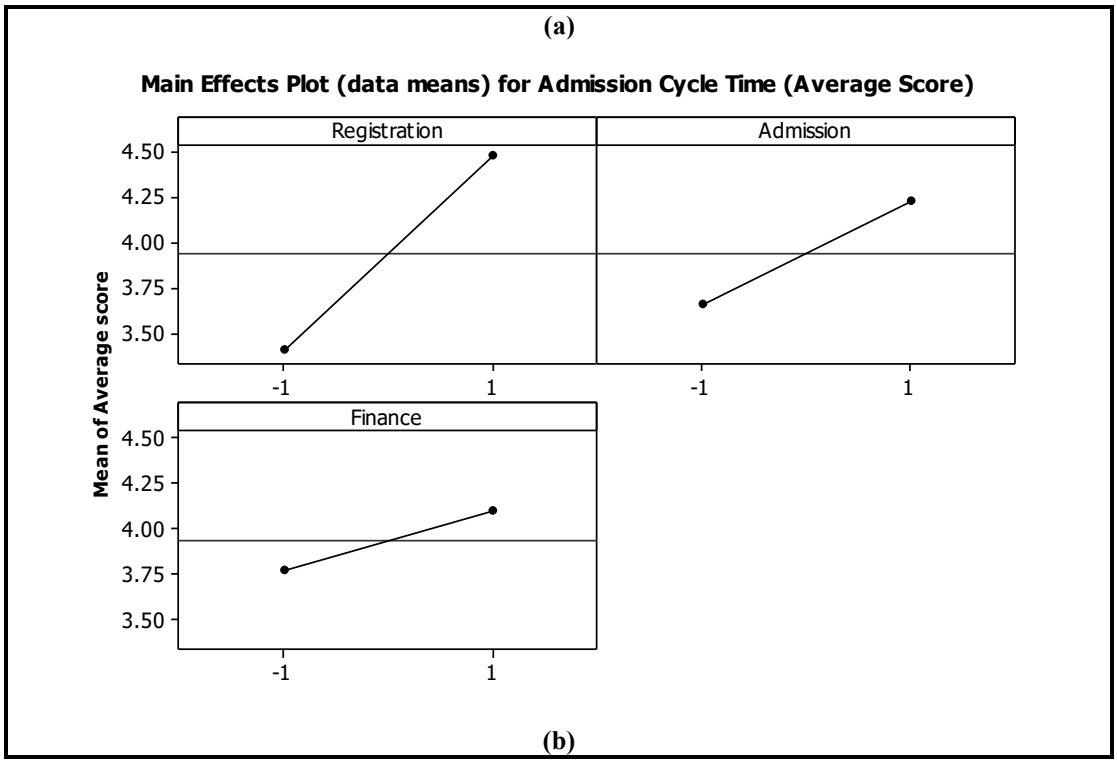

Figure 11. (a) Results from ANOVA, (b) Main effects plot for "Regsitration", "Admission", and "Finance"

4.2.4 Improve phase

The project team discussed the three major root causes as identified in the Analyze phase with the relevant personnel in the concerned departments to generate as many solutions as possible. Based on several brainstorming sessions, the following suggestions and solution options were proposed:

- Admission: One of the reasons of long service time in the Admission department is the missing documents. To avoid this, it was suggested to have a checkpoint before the admission process starts to ensure the availability of the required documents. It was also suggested to distribute task sheet prepared in the form of a flow chart among the new students at the checkpoint to clarify the exact steps they need to follow to complete the admission process.
- Finance: The new students currently need to visit the Finance department twice which also a reason of the long admission cycle time. To reduce the number of times the students need to make payments in the Finance department, it was suggested to complete all types of payments together in one step.
- Registration: The waiting time in the queue is usually very long in the Registration department. To avoid this, it was suggested to replace the "physical course registration step" by an "online course registration system", especially for those students who have no issues with IELTS and/or placement test. It was also suggested to handle existing students and new students separately during the admission period (i.e., to have different admission periods for new and existing students) to avoid long queues in the Registration department.

The implementation of the suggested solutions needs long term planning and management commitment. However, the effectiveness of the suggested solution options was tested by discrete event simulation in this phase. Simulation model is widely used in DMAIC as an effective and inexpensive tool for process improvement (Bhat, Gijo & Jnanesh, 2014, Murali & Prabukarthi, 2020). In this step, a simulation model is developed using ARENA simulation software (Figure 12), based on the process flow map (see Figure 4). In developing the simulation model, it is assumed that once a student enters the system, he/she will complete all required process steps and leave the system. It is also assumed that after completing a process step, the student will go ahead to the next step immediately, and thus the movement time between different process steps is not considered in calculating the admission cycle time. The distribution of student's arrival and service times at Admission, Finance, and Registration departments was determined based on the collected data in Measure phase and discussion with the employees of the concerned departments. In validating the simulation model, 120 data (replicate size, $n = 120$) on admission cycle time were generated by the simulation model. The replicate size of 120 was decided based on a margin of error of ±3.75 and 95% confidence interval (Banks et al., 2010). The normality assumption of the data collected from the original simulation model was confirmed (P-value = 0.828), and the validation of the simulation model was conducted by hypothesis testing. A single sample *t*-test (H_0: $\mu = 88$ & H_1: $\mu \neq 88$) shows that the mean admission cycle time generated by the simulation model is statistically equal to the actual mean cycle time of 88 minutes (P-value = 0.636). The validated simulation model is now modified following the suggested solutions under four scenarios as explained below. The modified models under the four scenarios ensure that no extra manpower or logistic support will be necessary.

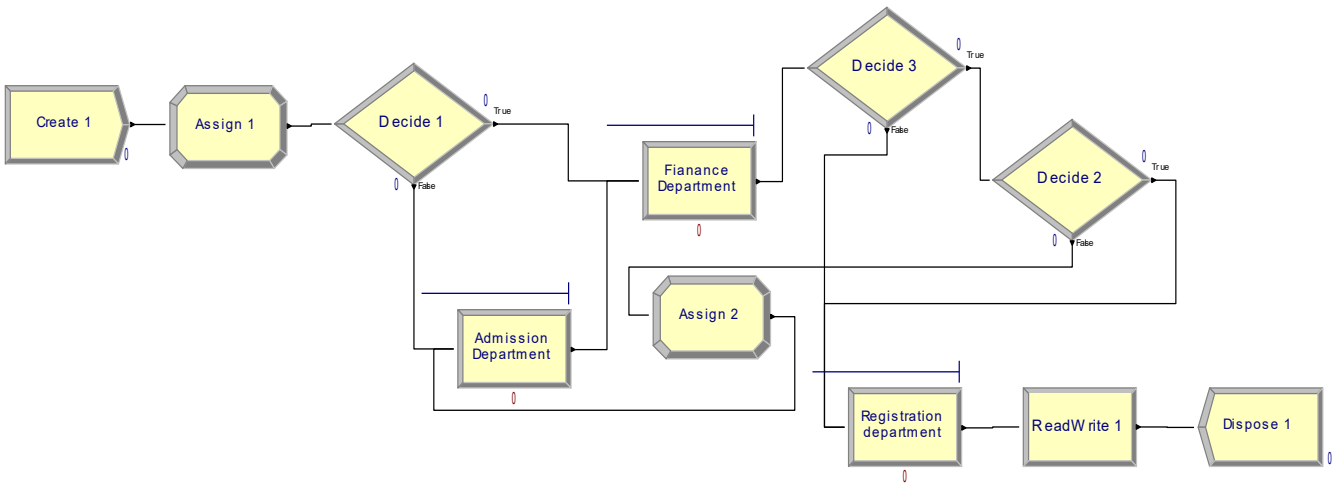

Figure 12. Original simulation model of the admission process

Scenario-1: Add a checkpoint at the beginning of the admission process. At this checkpoint, the documents of the new students will be checked to ensure the availability of the required documents before submitting them to the Admission department. A task sheet showing the steps of the admission process in terms of a flow chart will also be distributed among the new students to give a clear idea about the process steps they will need to follow to complete the admission process. Some of the available helper students (a group of senior students are

temporarily appointed in assisting the new students during admission period) can be utilized at the checkpoint. Addition of the checkpoint is expected to help to reduce the time required to complete the tasks at Admission department as the student's documents will be checked and a preliminary idea about the admission steps will be given to the students prior to entering the admission process. The original simulation model is modified under this scenario to include the checkpoint assuming that 3 helper students will assist the incoming new students at the checkpoint. It is also assumed that the time required to complete the process at the checkpoint is 25% of the service time taken by the admission department, and at the same time, since the required documents will be checked at the checkpoint, the service time taken by the Admission department will be reduced by 35%. The modified simulation model under this scenario was run and the output data (n = 120) were tested through a single sample t-test that the mean admission cycle time was less than the targeted value of 60 minutes (H_1: $\mu = 60$ & H_1: $\mu < 60$). The results of the hypothesis test show that the mean admission cycle time generated by the simulation model is not less than 60 minutes (P-value = 1.000), thus the proposed solution under this scenario is not feasible.

Scenario-2: Replace physical course registration step by an online course registration system. It was observed from the current process that the importance of the physical registration step is low, especially for students who have no issues with IELTS and/or placement test, therefore, it is suggested to replace the physical course registration step by an online course registration system from where the student can get his course schedule automatically. The original simulation model is modified under this scenario assuming that 5% of the new students will have issues with IELTS/placement test, and thus this 5% students will need to complete course registration physically at Registration department. The modified simulation model under this scenario was run (n = 120) and the output data were tested by a t-test following the same hypothesis mentioned in Scenario-1. The results of the hypothesis test show that the mean admission cycle time generated by the simulation model under this scenario was not less than 60 minutes (P-value = 1.000), thus the proposed solution under this scenario is not feasible.

Scenario-3: Reduce the number of times the students need to make payments in the Finance department. In the original process, the students need to visit the Finance department twice, once for paying for seat reservation, and another time for paying the tuition fees. The simulation model is modified under this scenario so that the students will need to visit the Finance department once to make all payments together and the payments information is sent from Finance department to Admission department electronically. The modified simulation model was run (n = 120) and the output data on the admission cycle time were tested following the same hypothesis mentioned in Scenario-1. The results of the t-test show that the mean admission cycle time generated by the simulation model under this scenario was not less than 60 minutes (P-value = 1.000), thus the proposed solution under this scenario is not feasible.

Scenario-4: The original simulation model is modified to combine both Scenarios 2 and 3 together under this scenario. That means 5% of the students will complete physical course registration and all other students will complete the course registration through online system. The students will then visit Finance department once to make all payments together. The modified simulation model was run and the output data (n = 120) on the admission cycle time were tested following the same hypothesis mentioned in the previous scenarios. The results of the t-test show that the mean admission cycle time generated by the simulation model under this scenario was significantly less than 60 minutes (P-value = 0.000), thus the proposed solution under this scenario is feasible. It is noted that the data on the admission cycle time in this scenario were not normal,

thus the data were transformed to normal (P-value = 0.817) by Johnson transformation before using the hypothesis test.

The results obtained from the five models (the original one and the four abovementioned scenarios) are represented by boxplots as shown in Figure 13. The modifications implemented in Scenario-4 are thus recommended and correspondingly the process flow map is modified for future use.

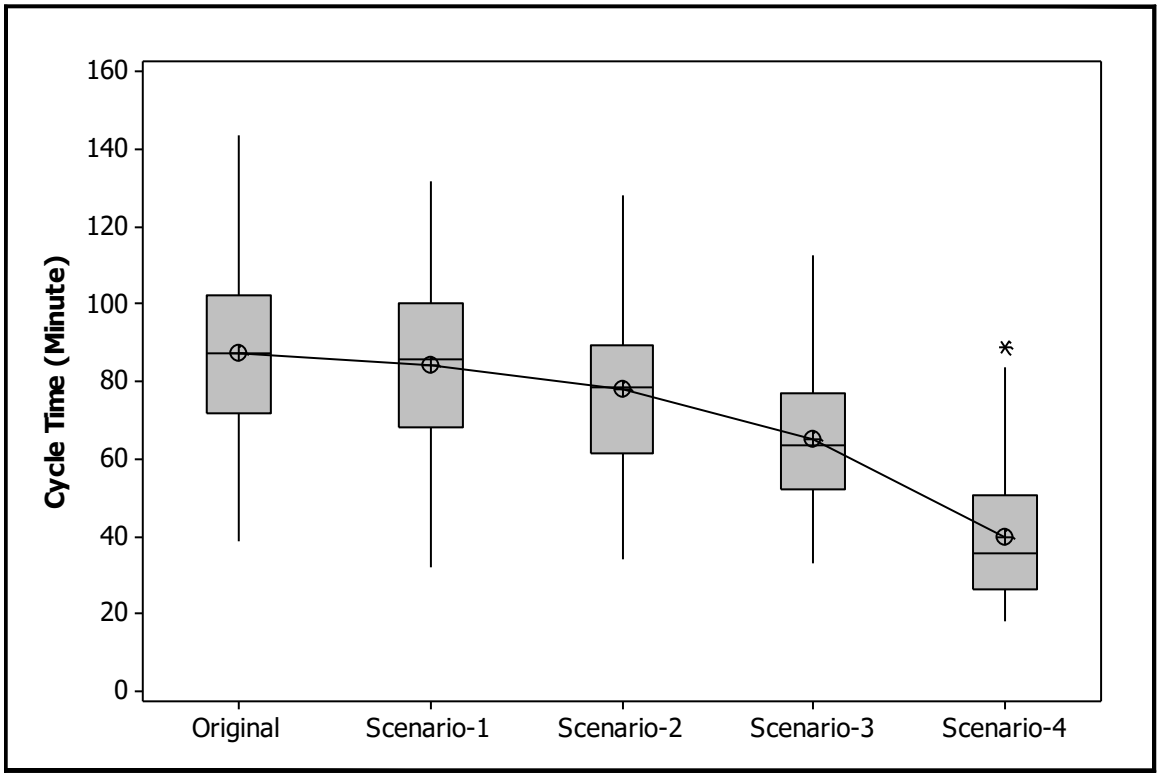

Figure 13. Boxplot of cycle times obtained under different scenarios

4.2.4 Control phase

This phase is the last step of the DMAIC methodology, and the objective of this step is to make sure that the improvement obtained in Improve phase will sustain over time. All the procedure followed in the study, along with the revised process flow map were documented for the future use. It was suggested to form an audit team including personnel from Admission, Finance and Registration departments to investigate the admission process from time to time, especially during the last few weeks of the admission period of each semester, and to prepare a performance report every semester for the directors of the concerned departments. Then, it was suggested that directors should have at least one meeting per semester with all process stakeholders to discuss the results and identified issues. It was also suggested to form a team of senior students to help the new students in understanding the steps of the admission process, specially at the proposed checkpoint. In addition, it was suggested to use control chart for continuous monitoring of the admission cycle time so that immediate action can be taken if any assignable cause occurs in the admission process.

4.3 Results and discussion

This study aims at implementing LSS methodology to improve the admission process of new students in a HEI. The preliminary investigation showed that the completion of the whole admission process of a new student in the case HEI takes 88 minutes, on average, which is quite high and creates dissatisfaction among the students and guardians. The implementation of the LSS project identified three major root causes which are mainly responsible for the long admission cycle time of the case HEI:

- Long waiting time in the queue (Registration department),
- Long time required to review the documents and enter the required information to the system (Admission department), and
- Number of payment steps (Finance department).

In addition, some other less significant causes were also identified during the execution of the project:

- Lack of knowledge about the admission process (Students).
- Lack of knowledge about the required documents (Students).
- Missing documents (Admission department).
- Time to make fees payments for new students (Finance department).
- Long time required to register courses for new students specially for those students having issues with IELTS and/or placement test (Registration department).

The project team generated four solution scenarios considering the above-mentioned root causes and investigated the effectiveness of the proposed solution scenarios using simulation. Finally, the results obtained from the best solution scenario were analyzed and compared with those of the current process. The improvement before and after the project implementation are visualized by a graphical representation as shown in Figure 14.

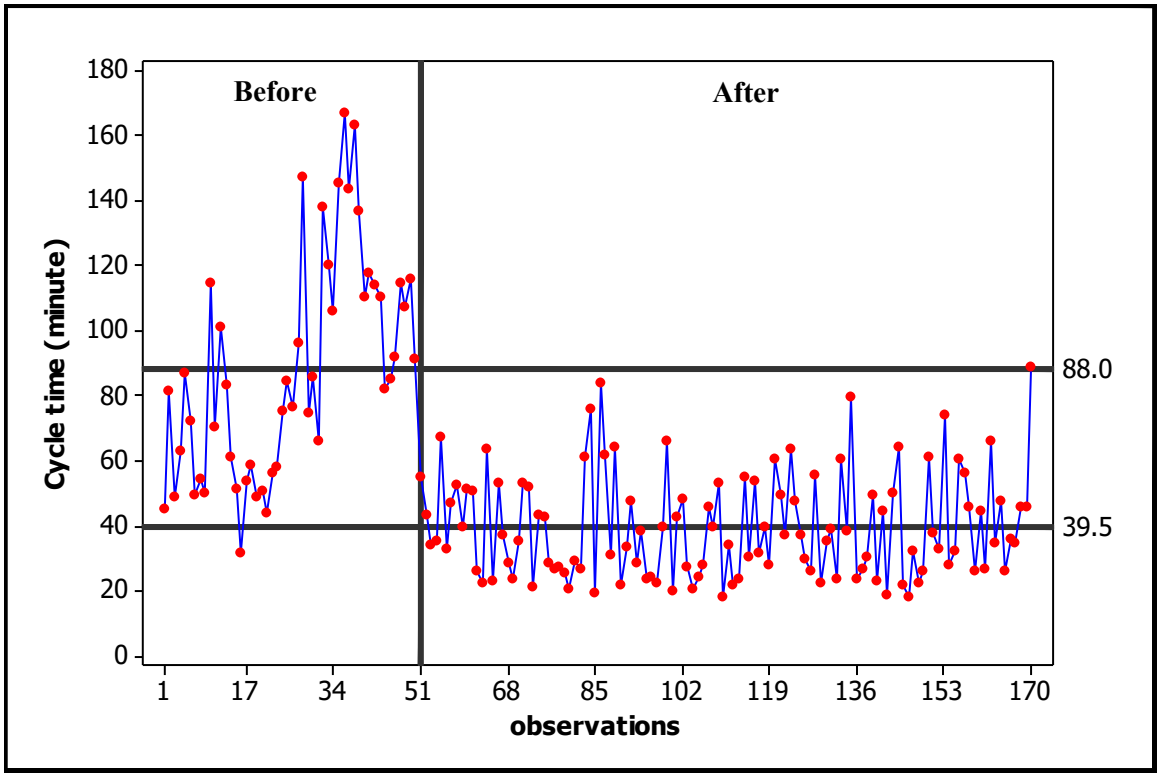

Figure 14. Admission cycle time before and after the project implementation

The improved results, along with the original results (found in Measure phase) are listed in Table 4.

Table 4. Improvement after project implementation

Project implementation	Mean cycle time (minute)	Standard deviation	PPM value	Sigma level
Before	88.0	34.2	784040.00	0.71
After	39.5	16.0	142857.14	2.57
Improvement (%)	55% (-)	53% (-)	81% (-)	72% (+)

Table 4 clearly demonstrates that the PPM value obtained from the recommended solution scenario has been reduced significantly compared to the original PPM value. As a result, the sigma level increased from 0.71 Sigma to 2.57 Sigma (i.e., the process is improved by about 72%), and correspondingly, the admission cycle time is reduced by about 55%. The research findings support that LSS has the potential to improve the administrative process such as admission process at HEIs.

5. Lessons learned and challenges faced

The implementation of the LSS project was the first initiative for process improvement in the case HEI. The systematic procedure followed in the LSS project in reducing admission cycle type was appreciated by the management of the concerned departments. The LSS project opens the door to implement more LSS projects in other departments for effective utilization of resources and minimizing wastes. More importantly, the involvement of a group of undergraduate students in implementing the LSS project provides a great opportunity for them to gain hands-on experience through implementing their academic knowledge in solving real world problems. The successful implementation of the LSS project paves the way for involving students in future LSS projects to be implemented in other departments of the HEI.

However, the LSS team faced several barriers and challenges in implementing the project. Some of the major challenges are discussed below:

- The concerned personnel in different departments had no idea about the LSS tools, and the terminologies used throughout the implementation of the project. The implementation team was required to spend extra time to clarify the DMAIC methodology and the techniques to the concerned personnel which highlight the importance of the LSS readiness of the case HEI as specified by Antony (2014).
- No historical data were readily available. This made the team's work difficult during execution of the DMAIC phases. Some data were collected by tracking the movement of students throughout the admission process. Tracking the students was not easy, especially during the last three weeks of the admission period of a semester.
- It was not easy to get help from the serving personnel in different departments because of their busy schedule, especially during the last three weeks of the admission period. The team also realized that the concerned departments were not well coordinated. This

highlights the requirement for setting effective communication channels among different departments. This finding also indicates the requirements for providing LSS training to the concerned personnel.

- Keeping the students engaged throughout the implementation of the project was not easy, because of lack of their sense of responsibilities, and at the same time, they were involved with other coursework and academic activities. However, the LSS project was also interesting to the students because of its practical nature.

Based on the experience gained from the implementation of the LSS project, the following suggestions are provided for a successful implementation of the future LSS projects in different areas of HEIs:

- Data collection is very time consuming, and it is not an easy task most of the time. This is because defining the CTQ characteristic in the service sector is quite difficult. The historical records may not be available, or the data may not be recorded in a systematic way. Thus, the LSS team should have a well-defined data collection plan.
- It is very important to use appropriate analytical tools to draw meaningful conclusions, especially in the Analyze and Improvement phases of the DMAIC methodology. However, the statistical analysis of the design of experiments (DOE) used in the Improve phase might not be easy to conduct. A questionnaire-survey is an effective tool to collect the required data in such a case.
- The concerned employees might not be very cooperative, specially at the initial phase of the project implementation. It is very important to gain the trust of the concerned employees to overcome this problem. This can be done by setting an open and friendly communication channel with them. Top management support is vital in this respect.
- The concerned employees are usually unfamiliar with the DMAIC methodology, and the relevant tools and techniques. Organizing a seminar/workshop/training to the employees of the case organization before starting the LSS journey could be very helpful in this respect.

6. Conclusions and future research

Lean, SS and LSS are popular business process improvement strategies widely used to promote business and operational excellence in manufacturing organizations. However, their applications in service sectors, especially in HEIs are still growing. Literature shows that very few articles focused on the application of LSS for improving administrative processes at HEIs, and the articles that handled admission and registration process used either only SS tools and/or qualitative research. This study implements LSS methodology to improve the admission process of new students in a case HEI. The study used a case study research methodology in which both qualitative and quantitative data is collected and analyzed during the execution of the project to draw meaningful conclusion. The deployment of the proposed LSS project helps in reducing the admission cycle time from 88 minutes to 39.5 minutes, which is equivalent to an improvement in process sigma level from 0.71 to 2.57 according to a targeted cycle time of 60 minutes. This improvement is achieved by employing several tools and techniques such as SIPOC diagram, process flow map, VSM, simulation, control chart, process capability analysis, Gemba Walk, and statistical analysis through the DMAIC phases. This improvement will not only satisfy the students

and guardians, but also reduce the workload on the employees, increase student overall satisfaction, and improve the reputation of the institute.

Because of difficulty in collecting the required data, the current study did not consider the time to get an initial acceptance through the online application while calculating the admission cycle time. In addition, the sample size used in the study is considered small. However, authors have a plan to collect more data for further validity of the results in the future. The estimation of financial benefit of the LSS project was also beyond the scope of the study. In this study, the proposed solution approaches were tested by simulation. A future project might investigate the effectiveness of the proposed solution approaches on the real system and conduct a cost-benefit analysis.

References

Alblooshi, M., Shamsuzzaman, M., Khoo, M.B.C., Rahim, A., & Haridy, S. (2020). Requirements, challenges, and impacts of Lean Six Sigma applications: a narrative synthesis of qualitative research. *International Journal of Lean Six Sigma*, 12(2), 318-367, doi:10.1108/IJLSS-06-2019-0067.

Anthony, S. & Antony, J. (2017). Lean Six Sigma in Academic Institutions—UK vs. Rest of the World. *Proceedings of 4th International Conference on Lean Six Sigma for Higher*, May 25–26, 2017, Purdue University, pp. 68-82. 2017, doi:10.5703/1288284316377.

Antony, J. (2014). Readiness factors for the Lean Six Sigma journey in the higher education sector. *International Journal of Productivity and Performance Management*, 63(2), 257-264. doi:10.1108/IJPPM-04-2013-0077.

Antony, J., Sivanathan, L., & Gijo, E. V. (2014). Design of experiments in a higher education setting. *International Journal of Productivity and Performance Management*, 63(4), 513-521. https://doi.org/10.1108/IJPPM-07-2013-0130.

Antony, J. (2015). Challenges in the deployment of LSS in the higher education sector: viewpoints from leading academics and practitioners. *International Journal of Productivity and Performance Management*, 64(4), 893-899. https://doi.org/10.1108/978-1-78769-929-820201005.

Antony, J. (2017). Lean Six Sigma for higher education. *International Journal of Productivity and Performance Management*, 66(5), 574-576. https://doi.org/10.1108/ IJPPM-03-2017-0063.

Antony, J., & Cudney, E. A. (2016). Lean six sigma journey in a UK higher education institute: challenges, projects, and key lessons learned. 123rd *ASEE Annual Conference and Exposition* 2016 – New Orleans, United States, 26-29 June 2016, American Society for Engineering Education. https://doi.org/10.18260/p.25527.

Antony, J., Ghadge, A., Ashby, S. A., & Cudney, E. A. (2018). Lean Six Sigma journey in a UK higher education institute: a case study. *International Journal of Quality & Reliability Management*, 35(2), 510-526. https://doi.org/10.1108/IJQRM-01-2017-0005.

Antony, J., Krishan, N., Cullen, D., & Kumar, M. (2012). Lean Six Sigma for higher education institutions (HEIs): Challenges, barriers, success factors, tools/techniques. *International Journal of Productivity and Performance Management,* 61(8), 940-948. https://doi.org/10.1108/17410401211277165.

Balzer, W. K, Francis, D. E., Krehbiel, T. C., & Shea, N. (2016). A review and perspective on Lean in higher education. *Quality Assurance in Education*, 24(4), 442-462. http://dx.doi.org/10.1108/QAE-03-2015-0011.

Banks, J., Carson, J. S., Nelson, B. L., & Nicol, D. M. (2010). *Discrete Event System Simulation*. New Jersey: Pearson Education.

Bhat, S., Gijo, E. V., & Jnanesh, N. A., (2014). Application of Lean Six Sigma methodology in the registration process of a hospital. *International Journal of Productivity and Performance Management*, 63(5), 613-643. https://doi.org/10.1108/IJPPM-11-2013-0191.

Box, T. M. (2006). Six Sigma quality: experiential learning. *S.A.M. Advanced Management Journal*, 71(1), pp. 20-23.

Burtner, J. (2004). The adaptation of Six Sigma methodology to the engineering education enterprise. *Proceedings of the ASEE Southeast Section Conference*, 4-6 April, 2004, Available at: http://www.asee-se.org/proceedings/ASEE2004/P2004007indusBUR.pdf [Accessed on June 18, 2020].

Butt, B. Z. & Rehman, K. (2010). A study examining the students satisfaction in higher education. *Procedia Social and Behavioral Sciences*, 2, 5446-5450. doi:10.1016/j.sbspro.2010.03.888.

Cudney, E. A., Venuthurumilli, S. S. J., Materla, T., & Antony, J. (2020). Systematic review of Lean and Six Sigma approaches in higher education, *Total Quality Management & Business Excellence*, 31(3-4), 231-244. doi: 10.1080/14783363.2017.1422977.

Dey, A. K. (2007). A Lean approach to improve course curriculum of MBA. *Business Perspective,* 9, 109-128. https://ssrn.com/abstract=1482612.

Dharmayanti, D., Semuel, H., & Devie (2018). The Students Satisfaction, Student Loyalty, Competitive Advantage and Financial Sustainability on Private Universities in Surabaya. *Advances in Social Sciences Research*, 5(10), 266-275. doi:10.14738/assrj.510.5431.

Douglas, J. A., Antony, J., & Douglas, A. (2015). Waste identification and elimination in HEIs: the role of Lean thinking. *International Journal of Quality and Reliability Management*, 32(9), 970-981. https://doi.org/10.1108/IJQRM-10-2014-0160

Elliott, K. M. & Shin, D. (2002). Student Satisfaction: an alternative approach to assessing this important concept. *Journal of Higher Education Policy and Management*, 24(2), 197-209. https://doi.org/10.1080/1360080022000013518.

El-Sayed, M., El-Sayed, J., Morgan, J., & Cameron, T. (2011). Lean program and course assessments for quality improvement. *International Journal of Process Education*, 3(1), 65-72.

Emiliani, M. L. (2004). Improving business school courses by applying lean principles and practices. *Quality Assurance in Education*, 12(4), 175-187. https://doi.org/10.1108/09684880410561596.

Gibson, A. (2010). Measuring business student satisfaction: a review and summary of the major predictors. *Journal of Higher Education Policy and Management*, 32(3), 251-259. https://doi.org/10.1080/13600801003743349.

Goffnett, S. P. (2004). Understanding Six Sigma: implications for industry and education. *Journal of Industrial Technology*, 20(4), 1-10.

Gupta, S. K., Antony, J., Lacher, F., & Douglas, J. (2020). Lean Six Sigma for reducing student dropouts in higher education– an exploratory study. *Total Quality Management & Business Excellence*, 31(1-2), 178-193. doi: 10.1080/14783363.2017.1422710.

Haerizadeh, M. & Vijaya Sunder, M., (2019). Impacts of Lean Six Sigma on improving a higher education system: a case study. *International Journal of Quality & Reliability Management*, 36(6), 983-998. https://doi.org/10.1108/IJQRM-07-2018-0198.

Hess, J. D. & Benjamin, B. A. (2015). Applying Lean Six Sigma within the university: opportunities for process improvement and cultural change. *International Journal of Lean Six Sigma*, 6(3), 249-262. https://doi.org/10.1108/IJLSS-12-2014-0036.

Hoerl, R. & Bryce, G. R. (2004). What influence is the Six Sigma movement having in universities? What influence should it be having? *ASQ Six Sigma Forum Magazine*, 3(2), 37-40.

Holmes, M. C., Kumar, A., & Jenicke, L. O. (2005). Improving the effectiveness of the academic delivery process utilizing Six Sigma. *Issues in Information Systems*, 2(1), 353-359.

Holmes, M., Jenicke, L., & Hempel, J. (2015). A framework for Six Sigma project selection in higher educational institutions, using a weighted score card approach. *Quality Assurance in Education*, 23(1), 30-46. https://doi.org/10.1108/QAE-04-2014-0014.

Iruloh, B-R, N. & Ugwu, C. J. (2017). Key Dimensions of Educational Experiences Associated With Overall Undergraduate Students' Satisfaction with Tertiary Institutions in Rivers State, Nigeria. *American Journal of Educational Research*, 5(1), 97-102. http://pubs.sciepub.com/education/5/1/15.

Jenicke, L. O., Holmes, M. C., & Pisani, M. J. (2013). Approaching the challenge of student retention through the lens of quality control: a conceptual model of university business student retention utilizing Six Sigma. *Journal of College Student Retention Research Theory and Practice*, 15(2), 193-214. https://doi.org/10.2190/CS.15.2.d.

Jenicke, O. L., Kumar, A., & Holmes, M. C. (2008). A framework for applying Six Sigma improvement methodology in an academic environment. *The TQM Journal*, 20(5), 453-462. https://doi.org/10.1108/17542730810898421.

Kotler, P., and Karen F.A. Fox. 1995. Strategic Marketing for Educational Institutions Second Edition, Englewood Cliffs, New Jersey: Prentice-Hall, Inc.

Kumi, S., & Morrow, J. (2006). Improving self service the Six Sigma way at Newcastle university library. *Electronic Library and Information Systems*, 40(2), 123-136. https://doi.org/10.1108/00330330610669253.

Laux, C., Li, N., Seliger, C., & Springer, J. (2017). Impacting Big Data analytics in higher education through Six Sigma techniques, *International Journal of Productivity and Performance Management*, 66(5), 703-720. https://doi.org/10.1108/IJPPM-09-2016-0194.

Li, N., Laux, C. L., & Antony, J. (2019). How to use Lean Six Sigma to improve service processes in Higher Education: A Case Study. *International Journal of Lean Six Sigma*, 10(4), 883-908. doi: 10.1108/IJLSS-11-2018-0133.

Lu, J., Laux, C., & Antony, J. (2017). Lean Six Sigma leadership in higher education institutions, *International Journal of Productivity and Performance Management*, 66(5), 638-650. https://doi.org/10.1108/IJPPM-09-2016-0195.

Mahmood, W. N. M., Dangi, M. R. M., & Ali, K. A. M. (2014). Investigating Students' Satisfaction Level on Implicit Services of Malaysian Public Higher Education Institutions. *Gading Business and Management Journal*, 18(1), 41-59. https://www.semanticscholar.org/paper/Investigating-Students%E2%80%99-Satisfaction-Level-on-of-Mahmood-Dangi/f8f471fa717b0aded501e80528191143f0e0a637.

Montgomery, D. C. (2019). *Introduction to Statistical Quality Control*. New York: Wiley.

Murali, C. S. & Prabukarthi, A. (2020). Productivity improvement in furniture industry using lean tools and process simulation. *International Journal of Productivity and Quality Management*, 30(2), 214-233. doi: 10.1504/IJPQM.2020.107812.

Nadeau, S. (2017). Lean, Six Sigma and Lean Six Sigma in Higher Education: A Review of Experiences around the World. *American Journal of Industrial and Business Management*, 7, 591-603. https://doi.org/10.4236/ajibm.2017.75044.

Noor, K. B. M. (2008). Case study: a strategic research methodology. *American Journal of Applied Sciences*, 5(11), 1602-1604.

Nunnally, J.C. (1978), *Psychometric Theory,* McGraw-Hill, New York.

Oko, A. & Kang, P. S. (2015). Lean Six Sigma approach to improve the admissions process for a Nigerian HE Institute. *International Journal of Scientific and Engineering Research*, 6(5), 368 – 378. http://hdl.handle.net/2086/11008.

Ongy, E. E. (2016). Analysis of College Enrollment System Using Six-Sigma (DMAIC) Methodology, *Journal of Educational and Human Resource Development*, 4, 133-149.

Psychogios, A., Atanasovski, J., & Tsironis, L. (2012). Lean Six Sigma in a service context. *International Journal of Quality & Reliability Management*, 29(1), 122-139. https://doi.org/10.1108/02656711211190909.

Pyzdek, T. & Keller, P. (2014). *The Six Sigma Handbook*. *McGraw Hill*. doi:10.1036/0071415963.

Ramanan, L., Kumar M., & Ramanakumar, K. (2014). SIX SIGMA-DMAIC framework for enhancing quality in engineering educational institutions. *International Journal of Business and Management Invention*, 3(1), 36-40.

Shamsuzzaman, M., Alzeraif, M., Alsyouf, I., & Khoo, M.B.C. (2018). Using Lean Six Sigma to improve mobile order fulfillment process in a telecom service sector. *Production Planning & Control*, 29(4), 301-314. https://doi.org/10.1080/09537287.2018.1426132.

Sinha P. K. & Mishra N. M. (2013). Applying Lean thinking to higher education – A strategy for academic excellence. *Indian Journal of Applied Research*, 3(10), 1-4.

Svensson, C., Antony, J., Ba-Essa, M., Bakhsh, M., & Albliwi, S. (2015). A Lean Six Sigma program in higher education. *International Journal of Quality & Reliability Management*, 32(9), 951-969. https://doi.org/10.1108/IJQRM-09-2014-0141.

Thomas, A. J., Francis, M., Fisher, R., & Byard, P. (2016). Implementing Lean Six Sigma to overcome the production challenges in an aerospace company. *Production Planning & Control*, 27(7-8), 591-603. doi:10.1080/09537287.2016.1165300.

Thomas, A., Antony, J., Haven-Tang, C., Francis, M., & Fisher, R. (2017). Implementing Lean Six Sigma into curriculum design and delivery–a case study in higher education. *International Journal of Productivity and Performance Management*, 66(5), 577-597. https://doi.org/10.1108/IJPPM-08-2016-0176.

Vijaya Sunder, M. & Antony, J. (2018). A conceptual Lean Six Sigma framework for quality excellence in Higher Education Institutions. *International Journal of Quality & Reliability Management*, 35(4), 857-874. Doi:10.1108/IJQRM-01-2017-0002.

Vijaya Sunder, M. & Mahalingam, S. (2018). An empirical investigation of implementing Lean Six Sigma in Higher Education Institutions. *International Journal of Quality & Reliability Management*, 35(10), 2157-2180. https://doi.org/10.1108/IJQRM-05-2017-0098.

Vijaya Sunder, M. (2014). Quality excellence in higher education system through Six Sigma: student team engagement model. *International Journal of Six Sigma and Competitive Advantage*, 8(3-4), 247-256, https://doi.org/10.1504/IJSSCA.2014.067529.

Vijaya Sunder, M. (2016). Lean Six Sigma in higher education institutions. *International Journal of Quality and Service Sciences*, 8(2), 159-178. http://dx.doi.org/10.1108/IJQSS-04-2015-0043.

Waterbury, T. (2015). Learning from the pioneers: A multiple-case analysis of implementing Lean in higher education. *International Journal of Quality & Reliability Management*, 32(9), 934-950. https://doi.org/10.1108/IJQRM-08-2014-0125.

Wiegel, V. & Brouwer-Hadzialic, L. (2015). Lessons from higher education: adapting Lean Six Sigma to account for structural differences in application domains. *International Journal of Six Sigma and Competitive Advantage*, 9(1), 72-85. https://doi.org/10.1504/IJSSCA.2015.070104.

Womack, J. (2011). *Gemba Walks*. Lean Enterprise Institute, Inc.

Woodside, A. G. (2010). *Case Study Research: Theory, Methods and Practice*. Bingley, UK: Emerald Group Pub. Ltd.

Yin, R. K. (2009). *Case Study Research: Design and Methods*. Thousand Oaks, CA:Sage. doi: https://doi.org/10.33524/cjar.v14i1.73.