APPLICATION OF SIX SIGMA IN HIGHER EDUCATION QUALITY ASSURANCE

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Abstract:
Quality management in higher education has always been of utmost importance. It has become an even more important issue in the last years as a result of the increased demands by stakeholders and competitors. Although the Six Sigma concept has been successfully implemented in manufacturing industry for many decades and in the service sector in the last decade, its implementation in the quality assurance of higher education intuitions is still lacking.

The purpose of this paper is to show that higher education providers have a great scope of implementing the Six Sigma concept. To achieve this objective, we present the Define-Measure-Analyze-Improve-Control (DMAIC) model. The application of this model in HEIs can help in better understanding of the university processes and in their quality assurance.

Keywords: Six Sigma, DMAIC, higher education, higher education quality and quality.

JEL classification: C40, C49, I23.

1. Introduction

The concept of excellence is a cornerstone of higher education (HE). Universities have been focusing on quality improvement since 1990s, as a result of the increased competition for funding and students. However, the quest for assurance and continuous improvement of quality in higher education at European level has been moved into the focus in recent years owing to the increased autonomy of universities, the budget crunches and cuts in state funding, the growing competition pressure by private HEIs, higher needs and expectations from students and other stakeholders in terms of quality of HE as well as the rapid growth in the two-way internationalisation of HEIs.

Since 1999 quality assurance developments in European HEIs have largely been driven by the Bologna Declaration. One of the main goals of the Bologna Declaration was to encourage European cooperation in quality assurance of HE by developing comparable criteria and methodologies. In addition to new curricular structures, Bologna was supposed to enhance quality in teaching and offer more flexible learning ways to students.

Beyond the contribution of Bologna declaration to higher quality in European HEIs, the development of the "Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG)" by the European Association for Quality Assurance in Higher Education (ENQA) in co-operation and consultation with its member agencies and the other members of the "E4 Group" (ENQA, EUA, EURASHE and ESU), which were adopted by the Ministers of Education in 2005, are the biggest contribution to quality improvement in HE at the European level. In the European HE area quality assurance system is based on the autonomy of each HEI and its responsibility to deliver high quality education to the stakeholders. Assuring and improving quality in HE is especially important for the post-communist countries that strive to build skilled workforce as a precondition for achieving strong and sustainable economic growth. It is a key element in the reform of HE in Western Balkan countries and one of the prerequisites for joining the European educational area.
The quality of higher education in the Republic of Macedonia relies on four pillars: the law on higher education, the Accreditation and Evaluation Board which is an independent body in charge of the (re) accreditation of higher education study programmes and monitoring and developing the quality of higher education across public and private HEIs, the internal quality assurance within HEIs themselves and students opinion. The quality assurance systems in higher education in the Republic of Macedonia are well developed (positive mission statements, performance criteria, complex guidelines for processes such as external evaluation, institutional self-evaluation reports, and a ranking system aimed at demonstrating the quality of provision). However, there are significant discrepancies between the vision and its implementation which might have a negative impact on stakeholders' efforts to improve quality. This, in turn, has led the HEIs in these countries, like their counterparts worldwide to look at new approaches to quality assurance and continuous improvement.

HEIs institutions have been applying the Six Sigma concept in the last few decades to improve quality of their processes and increase customer satisfaction. In spite of that, the extensive literature review has revealed a lack of research in Six Sigma implementation in the higher education area. The objective of this paper is to show that HEIs have a great scope of implementing the Six Sigma concept. To achieve this objective we present the core tool used to drive Six Sigma projects, that is the simple performance improvement model, known as Define-Measure-Analyze-Improve-Control (DMAIC) model. The application of the DMAIC model in HEIs can help in better understanding of the higher education processes and in the quality assurance.

2. The need for quality and quality assurance in higher education

Defining quality is the first step towards defining quality assurance. Quality has been defined differently in different contexts. The British Standard Institution (BSI) defines quality as "the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs" (BSI, 1991).The traditional definition of quality: "Quality means fitness for use" is based on the viewpoint that products and services must meet the requirements of those who use them (Montgomery, 2009, p. 5). The modern definition of quality: "Quality is inversely proportional to variability" (Montgomery, 2009, p. 6) implies that if variability in the important characteristics of a product decreases, the quality of the product increases. It also leads to the following definition of quality improvement: “Quality improvement is the reduction of variability in processes and products” (Montgomery, 2009, p. 6). Since variability can only be described in statistical terms, statistical methods play a central role in quality improvement efforts.

Quality in higher education encompasses a wide range of definitions among which the most accepted are "fitness for purpose" (Juran, 1988) and "value for money”.

Quality as fitness for purpose can be defined as system and process control. It focuses on the establishment of national and institutional structures for evaluating quality (Schwarz & Westerheijden, 2004), and it takes on the practice of assuring structural, organisational, and managerial processes within institutions (Westerheijden et al., 2007).

Another popular definition of quality in higher education “value for money “associates quality with expense and economic exchange. “The accounts of quality as a virtue of professional practice define quality in terms of its value for promoting stakeholders’ intrinsic excellence and motivation in wanting to learn and to teach in a professional way. To say that quality is a virtue of professional practice is to insist that quality is one of the things that makes higher education valuable and worth participating in, and that makes learning enjoyable” (Cheng, 2016, p. XI)

According to Article 11 of the World Declaration on Higher Education published by the United Nations, quality in higher educationis a multi-dimensional concept, which should embrace all its functions and activities: teaching and academic programmes, research and scholarship, staffing, students, buildings, faculties, equipment, services the community and the academic environment. It should take the form of internal self-evaluation and external review, conducted openly by independent specialists, if possible with international expertise, which are vital for enhancing quality.

“Quality assurance is the set of activities that ensures the quality levels of products and services are properly maintained and that supplier and customer quality issues are properly resolved. Documentation of the quality system is an important component. Quality system documentation involves four components: policy, procedures, work instructions and specifications, and records. Development, maintenance, and control of documentation are important quality assurance functions" (Montgomery, 2009, p. 17).

According to Glanville (2006) quality assurance generally includes all the policies, processes, activities and mechanisms by which quality assurance of higher education is acknowledged, sustained and developed”. Quality assurance system in higher education institutions are the activities offering quality services to satisfy the minimum needs of all parties benefiting from higher education facilities and giving them confidence such as inspection, evaluation and review. The quality in higher education consists of accreditation system evaluating higher education’s input, valuation system evaluating output and total quality system designing, planning and implementation of the processes.

There are many definitions of quality assurance in higher education which can be classified in two groups: broad definitions focusing on a central goal or outcome and specific definitions that identify specific aspects of quality that reflect desired inputs and outputs (Schindler et al, 2015).

In spite of the wide range of different definitions, they have some elements in common. First, many of them define quality assurance as a set of processes, policies, or actions performed externally or internally. Second, they include aspects of quality that are related to accountability. However, there is an increasing need for a greater emphasis on continuous improvement (Schindler et al, 2015).

3. Theoretical foundation of the Six Sigma concept

The Six Sigma concept was first developed in Motorola Inc. in 1984 as a response to the threat of Japanese competition in the electronics industry. In statistics the Greek letter sigma (σ) denotes standard deviation. The basic idea behind the introduction of the Six Sigma concept in Motorola is: to reduce defects and variation in the process so that the specification limits are at least six standard deviations from the mean, to increase customer satisfaction and increase profits. Motorola Inc. has reported saving upwards of 16 billion dollars by using the Six Sigma concept over the years. Originally developed and implemented by manufacturing, today the Six Sigma concept has been widely implemented by major leaders both in manufacturing and services. However, services were for a long period of time, skeptic concerning possibility of applying Six Sigma to their processes. According to Kumar et al. (2008) one of the most common myths about Six Sigma is that it is good only for manufacturing processes because the application of Six Sigma was originally limited to manufacturing and the application of Six Sigma has difficulties and challenges, especially in service. It is true that current service sector has been considerably slower in incorporating Six Sigma than the manufacturing sector (Furterer and Elshennawy, 2005), however more and more companies take advantage of Six Sigma in cost reduction and customer satisfaction.

Investigating over forty articles concerning six sigma in services, Chakrabarty and Tan (2007) find that six sigma is felt to be difficult to implement in services because services' processes cannot be amended easily. Hensley and Dobie (2005) pointed out the following problems in implementing Six Sigma in services: problems with data collection, difficulties in measuring customer satisfaction and problems with quantification and measurement of data sub processes. Those problems are similar with the ones expressed by Coronado and Antony (2002) and Rajamanoharan and Collier (2006).

Six Sigma has evolved over the last thirty years and so has its definitions. Six Sigma has many definitions, ranging from literal, conceptual, and practical definitions.

Six Sigma could be viewed at three different levels at the same time: as a metric, as a methodology, and as a management system (Andersson et al., 2006; Arnheiter and Maleyeff, 2005).

As a metric, Six Sigma denotes a population's standard deviation and is a measure of variation about mean. It had its foundation in the work of Carl Frederick Gauss whose pioneer work includes probability distribution which has a symmetric distribution about its mean. "Under six-sigma quality, the probability that any specific unit of the hypothetical product above is nondefective is 0.9999998, or 0.2 ppm. When the six-sigma concept was initially developed, an assumption was made that when the process reached the six-sigma quality level, the process mean was still subject to disturbances that could cause it to shift by as much as 1.5 standard deviations off target. Under this scenario, a six-sigma process would produce about 3.4 ppm defective. However, we can only make predictions about process performance when the process is stable; that is, when the mean (and standard deviation, too) is constant. If the mean is drifting around, and ends up as much as 1.5 standard deviations off target, a prediction of 3.4 ppm defective may not be very reliable, because the mean might shift by more than the "allowed" 1.5 standard deviations. Process performance isn't predictable unless the process behavior is stable. However, no process or system is ever truly stable, and even in the best of situations, disturbances occur. These disturbances can result in the process mean shifting off-target, an increase in the process standard deviation, or both. The concept of a six-sigma process is one way to model this behavior. Like all models, it's probably not exactly right, but it has proven to be a useful way to think about process performance" Montgomery (2009, p. 29).

As Six Sigma has evolved, the literal definition of 3.4 DPMO or counting defects in products and processes has lost its importance. In order to be a successful business strategy, Six Sigma needs to have executive management support and an effective organizational structure. Breyfogle (2003 p. 22) claims " Six Sigma needs to become a business process management system that:

1. Understands and addresses process components and boundaries

2. Identifies and collectively utilizes process owners, internal customers/ external customers, and other stakeholders effectively

3. Creates an environment for effective project management where the business achieves maximum benefits

4. Establishes project measures that include key performance metrics with appropriate documentation

According to Adina-Petrua and Roxana (2014, p. 644) "Six Sigma is a business improvement methodology that focuses an organization on:

- Understanding and managing customer requirements
- Aligning key business processes to achieve those requirements
- Utilizing rigorous data analysis to minimize variation in those processes
- Driving rapid and sustainable improvement to business processes."

As a management system, Six Sigma ensures sustainable improvements, team work of production teams, bring business strategies in line with improvement efforts and accelerate results. It is when Six Sigma is implemented as a management system that organizations see the greatest impact (Breyfogle et al., 2001, p.45). According to Pyzdek and Keller (2009, p. 87) Six Sigma offers the opportunity for management to make data driven decisions by quantifying needs or wants of stakeholder groups relative to current level, and acting upon the data to reduce those critical gaps in performance. As such, the Six Sigma Management System incorporates both the Six Sigma metric and the Six Sigma methodology.

Six Sigma is a quality management methodology used to help companies improve their processes, products or services by discovering all of the problems within the company and taking appropriate actions in order to reduce and eliminate errors and defects. The ultimate goal is to diminish or eliminate variation within the company's processes. It is used by mid-level managers as a methodology to achieve quality improvement by reducing the defects in products, services and processes (Mitra, 2004).

The concept of Six Sigma can be applied to higher educational institutions which are characterized by a high degree of variability in the processes, such as different type of instruction by professors, variability in students' evaluation processes, variability in students' learning styles etc. After defining the problems, a solution can be developed using six sigma approach and models.

Ramasubramanian (2012, p.1) defines Six Sigma in education as "a business improvement methodology that focuses an institution on:

- Understanding and managing student's requirements,
- Aligning key business processes to achieve those requirements,
- Utilizing rigorous data analysis to minimize variation in those processes and
- Driving rapid and sustainable improvement to educational processes."

HEIs are facing a number of challenges when introducing Six Sigma, such as, defining the customer, the nature of the product, the difficulty in measuring quality and analyzing data, limitations of reward systems for employees and the influence of uncontrollable factors on student, faculty and organizational success (Jenicke et al 2008). In spite of many challenges and difficulties of implementing Six Sigma at higher education level, there are a number of examples of successful application of Six Sigma at universities The literature review indicates that a framework is needed to successfully apply Six Sigma to university processes (Jenicke, et al 2008).

4. Application of Six Sigma in higher education institutions - the DMAIC model

Six Sigma uses several proven frameworks. However the primary method in Six Sigma concept is a simple performance improvement model, known as Define-Measure-Analyze-Improve-Control (DMAIC). According to Montgomery (2013, p. 935) the define-measure-analyze-improve-control problem solving approach is the best approach that has evolved to date for the quality control and improvement aspect of quality management. "DMAIC is a structured problem-solving procedure widely used in quality and process improvement. It is often associated with six-sigma activities, and almost all implementations of six sigma use the DMAIC process for project management and completion." (Montgomery, 2013, p. 935)

In the first phase, the "define" phase, the project team defines the objectives and scope of the Six Sigma project, which can be either a process improvement and/or problem-solving project and confirms that the project is appropriate. Quality and business improvement via projects has its roots in Juran, who always urged a project-by-project approach to improving quality. "One widely used approach is basing projects on strategic business objectives. In this approach, defining the key set of critical business processes and the metrics that drive them is the first step toward successful project development. Linking those processes together to form an integrated view of the business then follows. Projects that focus on the key business metrics and strategic objectives, as well as the interfaces among critical business processes, are likely to have significant value to the company." (Montgomery, 2013, p. 48)

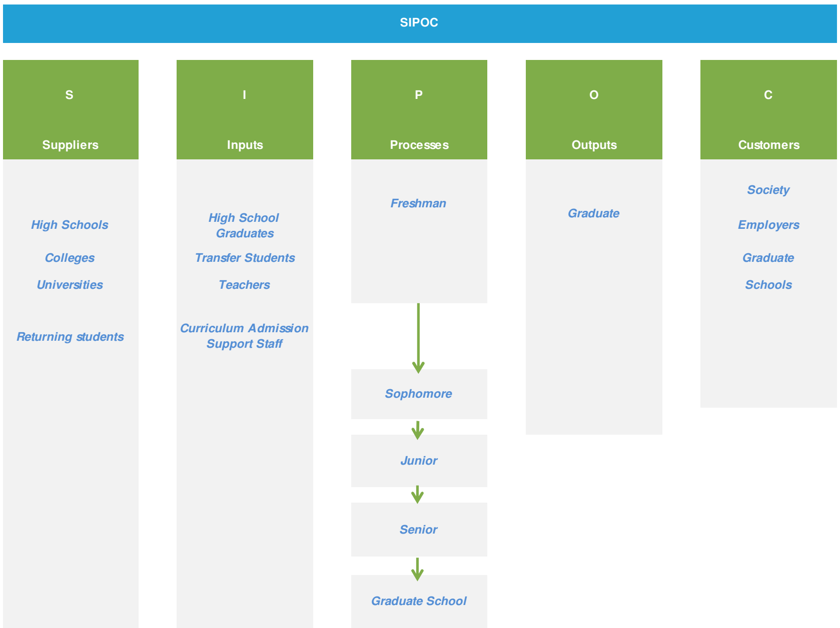
The project leader called a "Black Belt" or "Green Belt" plays the crucial role in the "define" phase. He coordinates with team members and other stakeholders to prepare the project charter (objectives, scope, budget, timeline and key players). Project Charter is a document that provides a framework and objective for a Six Sigma project.

Figure 1: Six Sigma Project Charter

In the define phase the external as well as internal customers are identified and their needs and requirements are clearly specified. According to Holmes et al. (2005) universities have difficulties in defining their customers and their products and services. Reavill (1998) developed a specific methodology to the stakeholder's identification of higher education, thinking on establishing the customers requirements as principal part in TQM (Total Quality Management). The author identified twelve stakeholder categories that contribute to or benefit from higher education: students, employers, the family and dependants of the student, universities and their employees, the suppliers of good and services, the secondary education sector, other universities, commerce and industry, the nation, the government, the national and local taxpayers and finally, professional bodies that guard the entry standards into a profession.The author affirms to be difficult to identify an order of priority of the relative importance from these customers, but for him the most important stakeholders are the students, the employers, the families and the universities and their employees. Doman (2011) suggests identifying the key players in and end-users of each process under examination. University's customers "consist of employers, graduate schools, society, and others, as some students may be selfemployed" (Mazumder, 2014, p. 6).

In the "measure" phase data is collected in order to assess the current situation, identify and rank potential factors that may be affecting process performance, define what should be measured, types of variations, accuracy of measurement, conduct the measurement, calculate current six sigma level and determine process capability. For that purpose, a SIPOC diagram is created. The acronym SIPOC stands for suppliers, inputs, process, outputs, and customers. It displays a cross-functional set of activities in a single and simple diagram which helps us identify process inputs and outputs, identify process owner, customers and suppliers and identify and establish control limits of the process. A SIPOC diagram for higher education developed by Mazumder (2014) is presented below.

Figure 2: A SIPOC diagram for higher education

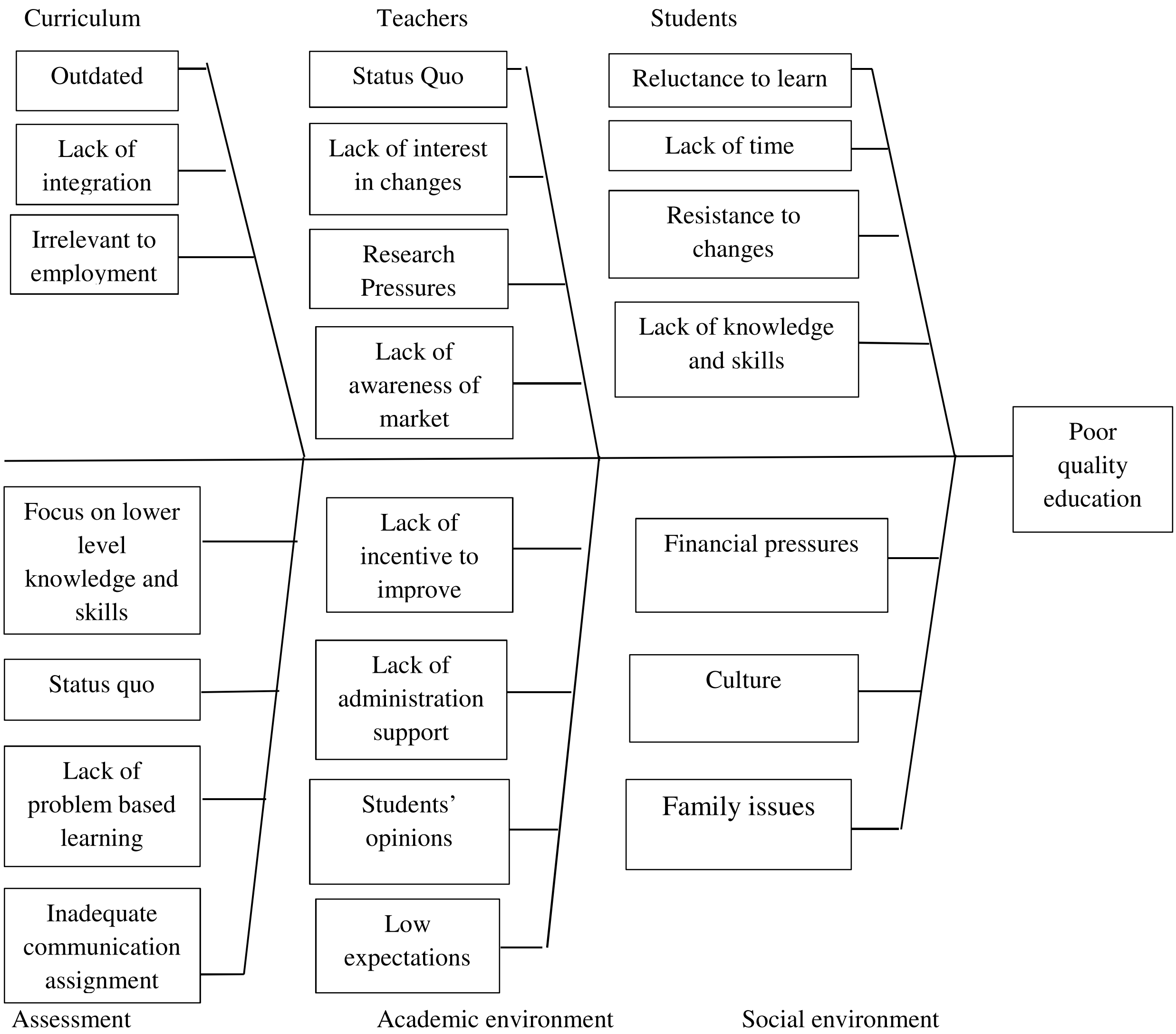


Source: Mazumder (2014, p. 7)

In the “analyze” phase the collected data are analyzed using statistical process control methods and tools. The purpose of this phase is to to identify the variables outside the control limits, to create a ranking list of the sources of variation and to determine the root causes of the process problems, to confirm the relationship between the suspected causes and the performance of the process, to suggest brainstorm ideas for processing students' improvements and identify which improvements have the biggest effect on students' requirements.

One of the statistical tools that can be used in this phase is the Ishikawa's cause and effect diagram, sometimes called the fishbone diagram. It displays the root causes from different sources. Their identification can help in making changes to improve quality of education.

Figure 3: Cause and Effect Diagram of Quality of Higher Education

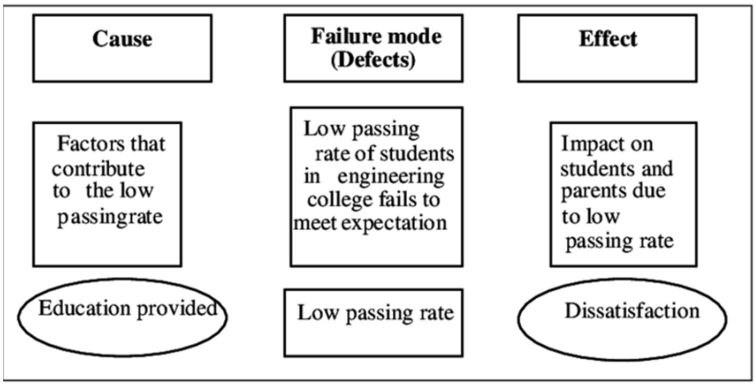


Source: Mazumder (2014, p. 11)

After identification of the variables that lie outside the control limits, in the "improve" phase, appropriate corrective actions are suggested. This phase is seen as the most challenging and the most important in academic environment, as it is crucial to student success and quality improvement. Quality tools used in this phase could be very well used for the improvement of organizations and institutions (Weinstein et al, 2008). One of these tools is the Failure Modes and Effects Analysis (FMEA) which helps project teams identify product features and process tasks that are more prone to defects and failure (see Figure 4). Armed with the insights that FMEA provides, project teams can enhance product quality and reduce errors by modifying existing processes or creating a new process to correct potential defects.

The last phase, the "control" phase determines how well the DMAIC process has been performed. In the "control" phase measures are taken to ensure that the results obtained in the improvement phase are institutionalized and maintained. "The key to success in achieving quality is to standardize the improvement process and fostering a six sigma or continuous improvement process in the organizational culture." Mazumder (2014, p.13). In this phase tracking of ongoing data is established and a plan for identifying when the process is out of control is prepared. The teams create a specific operating procedure for the specific process that includes the changes made.

Figure 4: Failure mode and effect analysis (FMEA)



Source: Kaushik and Khanduja, D. (2010, p. 476)

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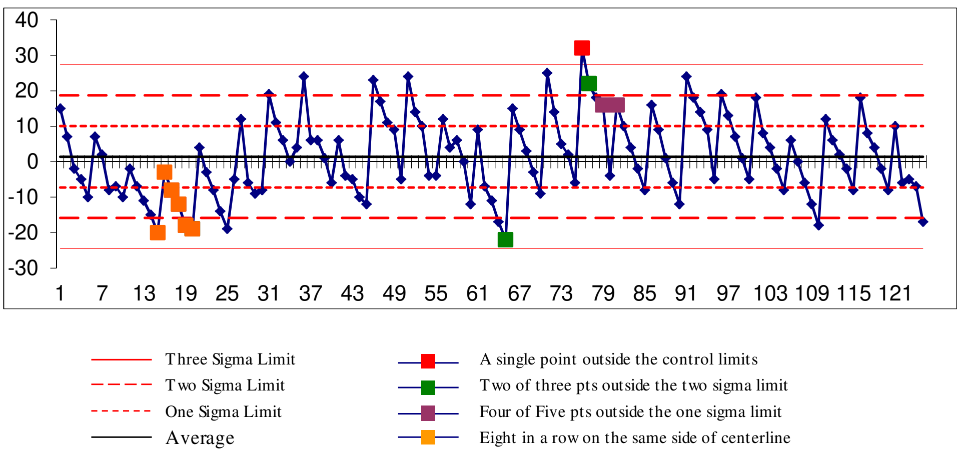
Control charts are an effective way of statistically keeping a track of performance and using the data for continuous improvement in Six Sigma methodology (Maleyeff and Kaminsky, 2002). Control charts are SPC techniques which help to determine if the process is under statistical control, the level of variation inherent in the process, and the direction of the nature of the variation (common cause or special cause).

Figure 5: Control chart



Unlike the widespread use of control charts for quality assurance in the manufacturing sector, they were applied to the field of HE quality measurement in the last few decades. According to Montgomery (2009, p. 213) "Transactional and service industry applications of SPC and related methodology sometimes require ingenuity beyond that normally required for the more typical manufacturing applications. There seems to be two primary reasons for this difference:

1. Most transactional and service businesses do not have a natural measurement system that allows the analyst to easily define quality.
2. The system that is to be improved is usually fairly obvious in a manufacturing setting, whereas the observability of the process in a nonmanufacturing setting may be fairly low.

Furthermore, the lack of a quantitative and objective measurement system in most nonmanufacturing processes complicates the problem.

The key to applying statistical process-control and other related methods in a nonmanufacturing environment is to focus initial efforts on resolving these two issues."

Van Krimpen-Stoop and Meijer (1999, 2001) constructed cumulative sum (CUSUM) control charts to develop a person-fit index in a computer adaptive testing (CAT) environment. Meijer (2002) applied the CUSUM-based person-fit index for identifying outliers in high-stakes certification testing. Armstrong and Shi (2009) further developed model-free CUSUM methods to detect person-fit problems. Using CUSUM charts, Veerkamp and Glas (2000) detected drifts in 1PL and 3PL item parameter estimates in a CAT environment. Omar (2010) used the Shewhart mean and standard deviation charts for ensuring quality in a measurement process for rating performance items in operational assessments.

A control chart is used in the control phase of DMAIC to help lock in the obtained results and develop an alarm system that will let you know that the process is out of statistical control. Other tolls used in this phase include: process/monitor / response plan, standardization process dashboards, capability studies, documentation, final report and presentation.

Between each of the abovementioned described phases in DMAIC there are "tollgates" at which project team presents its work to managers and "owners" of the process. "In a six-sigma organization, the tollgate participants also would include the project champion, master black belts, and other black belts not working directly on the project. Tollgates are where the project is reviewed to ensure that it is on track and they provide a continuing opportunity to evaluate whether the team can successfully complete the project on schedule. Tollgates also present an opportunity to provide guidance regarding the use of specific technical tools and other information about the problem." (Montgomery, 2009, p. 46).

At the end of the "control" phase, the project manager transfers ownership back to the process owner and shares the results with all stakeholders in order everyone to learn and benefit from them.

5. Benefits of the Six Sigma DMAIC model to HEIs

The Six Sigma DMAIC model offers several specific benefits to HEIs.

First and foremost, DMAIC is characterized by a very clear structure. This means that it analyzes a process carefully before suggesting any improvements. One of the main reasons why companies fail to implement improvements successfully is the lack of analysis before the implementation of the improvement.

As a structured approach, DMAIC provides HEIs with a road map for solutions which helps them solve problems from beginning to end, resulting with an increase of their bottom-line profits.

Additionally, DMAIC supports an analytical approach, allowing the HEIs to analyze the collected data. This helps the universities ensure accurate benchmarks for measuring or comparing current and past values.

DMAIC allows the HEIs to quantify improvements and find answers to complex problems. "Measures used in education tend to be lagging indicators. Because of the requirements of Six Sigma, team members identify leading indicators that reflect the success of projects. These indicators are generally called CTQ indicators or KPIs. Project metric or CTQ gets measured as part of the DMAIC flow before and after the execution of the project. This creates a culture of measuring KPIs and helps understand future areas for collecting data and validating the problems for continuous improvements" Vijaya (2014, p. 254).

Another advantage of DMAIC for HEIs is that it fosters cooperation and communication between different departments and promotes teamwork since different departments within the HEIs are involved in the application of the DMAIC model.

DMAIC creates visible processes using tools such as, the SIPOC diagram and process maps and makes easier the identification of causes of variation and reduction of variation in the process.

Six Sigma DMAIC requires that all stakeholders, and not only students, are considered and that their needs and requirements are included in overall process improvement.

Six Sigma seeks to improve bottom-line profits by reducing the hidden costs of poor quality. "These costs consume resources, people and time, and add very little to customer requirements. The proposed model targets in identifying such hidden opportunities, which holistically contributes to a higher failure cost for the educational institute." Vijaya (2014, p. 255).

6. Conclusion

Although originally developed and implemented in the manufacturing industry, in the last few decades the Six Sigma concept has been adopted by a number of HEIs institutions as a strategy for quality assurance. However, successful implementation of Six Sigma in HE sector demands a structure that suits the needs and requirements of HEIs. A number of six sigma models have been developed to improve quality in higher education The model presented in this paper – the DMAIC model, which is characterized by a very clear structure, provides HEIs with a practical and useful roadmap for adoption and implementation of the Six Sigma concept.

This is a very theoretical paper based on the existing literature and my experiences in the HE sector. In the future research I plan to carry out empirical studies in a number of HEIs to identify the main obstacles for implementation of the Six Sigma concept and develop a model that best suits their needs.

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