INTEGRATION OF LEAN SIX SIGMA & BUSINESS PROCESS MANAGEMENT TO DRIVE QUALITY & OPERATIONAL EXCELLENCE
(CASE STUDY AT INDUSTRIAL ENGINEERING DEPARTMENT)

THESIS

Submitted to International Program Department of Industrial Engineering in Partial Fulfillment of the Requirement for the Degree of Sarjana Teknik Industri at Universitas Islam Indonesia

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INTEGRATION OF LEAN SIX SIGMA & BUSINESS PROCESS MANAGEMENT TO DRIVE QUALITY & OPERATIONAL EXCELLENCE (CASE STUDY AT INDUSTRIAL ENGINEERING DEPARTMENT UII)

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ABSTRACT

Higher education is well known as one of the pillars and development partners to contribute to the infrastructure development in country equitable and beneficial to the improvement of the people's welfare. Many stakeholders involve and take for granted from this business to assure a good quality of graduation and meet requirement of customer on higher education. To improve and maintain that quality to meet the requirement, it is needed methods that can drive quality and operational excellence in higher education system. Due to this, the researcher tries to implement Lean Six Sigma & Business Process Management in higher education system. By analyzing and simultaneously using benefits of Lean Six Sigma and Business Process Management with synergetic approach, the findings are attempting to shed some lights on the way Lean Six Sigma is applied to higher education and on integrating Lean Six Sigma with Business Process Management for the development and maintaining university's continuous improvement.

Keywords: Higher Education; Lean Six Sigma; Business Process Management.

CHAPTER I

INTRODUCTION

1.1. Background

Higher education is one of the pillars and development partners to contribute to the infrastructure development in country equitable and beneficial to the improvement of the welfare of the people. The national development rests on improving the quality of human life, increased productivity and competitiveness of the people in the international world, and the realization of economic independence (Kemenristek Dikti RI, 2014). There is a prevailing belief that higher education has entered a new environment in which quality plays an increasing important role (Owlia & Aspinwall, 1997). Quality in higher education became an important issue due to ever increasing demand by stakeholders and competitive environment also facing challenges with resource constraints (Mazumder, 2014).

It is stated that quality of university education has recently become a subject of major concern. Students, their families, employers and the government want assurance that students will get "good quality" education and pass the university requirement. They will be glad to know that the students have received "quality education" and that their knowledge and competences in the area of study are at the world-class level. The way to quality is generic: identify your customer and make sure that your product meets or surpasses his needs. It is the knowledge and competence of students that will get them better jobs, make the students and their parents feel proud of their accomplishments and provide excellent reputation to schools (Stanislav & Willborn, 1997). Therefore, educational institutions require an innovative supporting methodology that helps in improving the quality of processes pertaining to the important functions particularly teaching, research, and service (Shoeibi & Zahmatdoost, 2015).

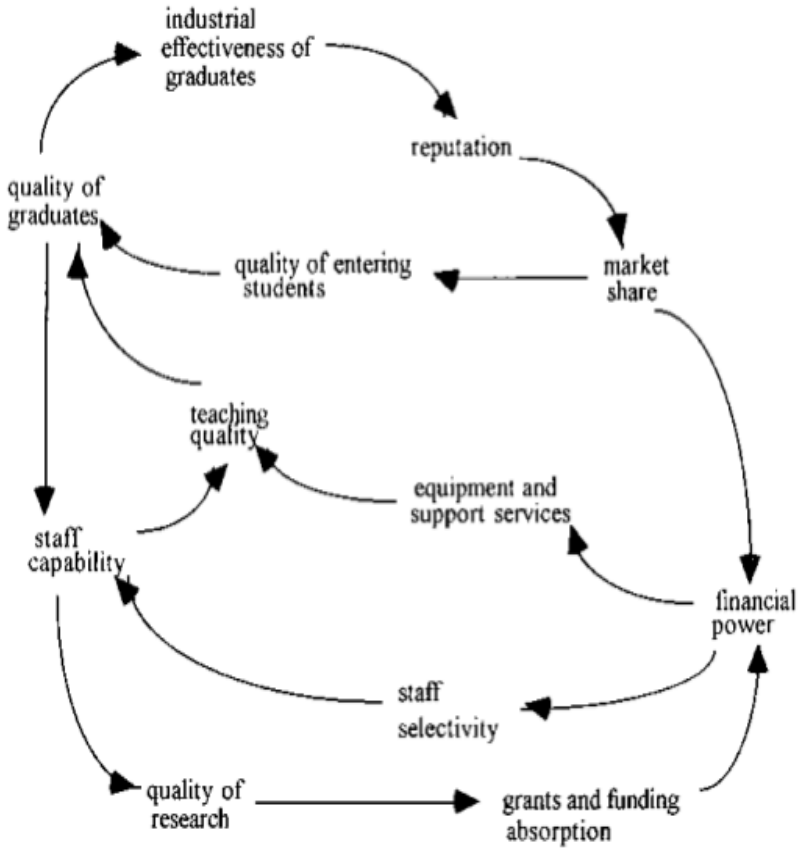


Figure 1.1 Causal diagram quality in higher education (Owlia & Aspinwall, 1997)

From this figure 1.1 depicts a causal diagram developed to show the dynamic behavior of quality-related factors in a higher education system. According to (Owlia & Aspinwall, 1997) analyzing higher education as a system reveals its complexity when compared to a manufacturing setting. But this positive feedback closed loop that present in this causal diagram in higher education system means that quality of student will be affected market share higher education, in other words affected the bottom line of higher education itself. Hence, the purpose of this study is to increase quality of graduates in order to get benefit for higher education and student itself.

Yogyakarta as a consequence of student city gives more graduates comparing to another city (Pusat Data dan Statistik Pendidikan, 2012). It needs to assure and improve the quality of graduates. Hence, The researcher tries to improve quality of graduates with case study in International Program Industrial Engineering Department University Islamic Indonesia (IP IE UII). One of many that influences quality of graduates IP IE UII is GPA above 3, on time study, and student retention. GPA above 3 is a common requirement or parameter for employer to scan quality of graduates.

Therefore, higher education should maintain performance lecturer and student in order to get this GPA. On time study is a duration that requires by student to pass 8 semesters and graduates without additional semester. Student retention is a process of ensuring student success or graduation in every semester that student through to decrease a loss of tuition revenue from students that either drop out, stopouts, and transfer to another university (Aljohani, 2014) (Crosling et al., 2009).

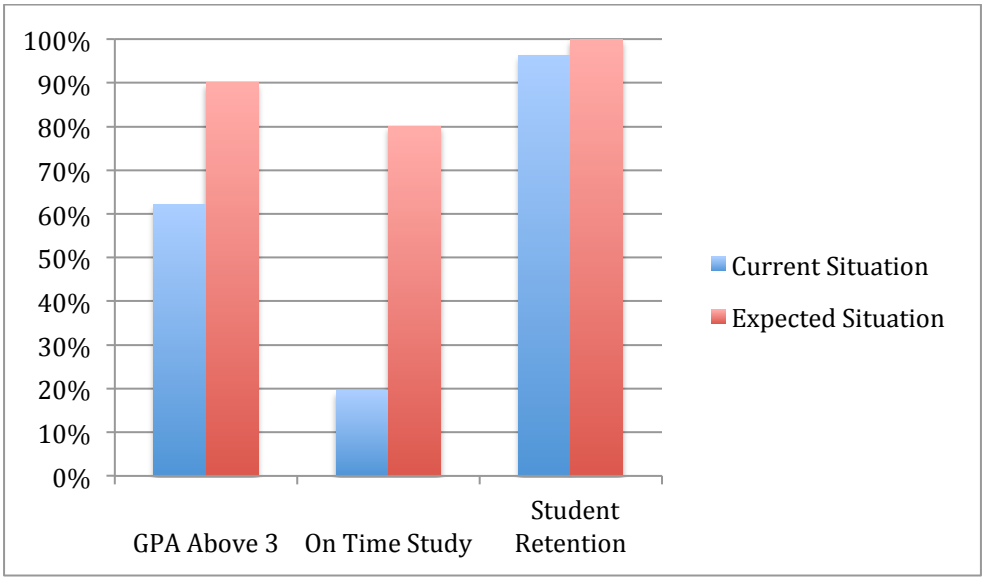


Figure 1.2 Gap Analysis IP IE UII from batch 2007 - 2012

From Figure 1.2, there is a gap quality from what management expected with the current condition summarized from batch 2007 – 2012. Based on this, researcher tries to minimize this gap with method that can analyze the symptom to search root causes of the problem and proposed improvement to chase expectation management, in other word improve quality of graduates.

This study is expected to be able to improve the quality of graduates so as to increase bottom line to university and become role mode to the other department and university in quality of graduates. LSS method is used as a driver to measure the quality of graduates and BPM is used as operational excellence so that all stakeholders in higher education system can view the flow of value and directly fix the problem.

1.2. Problem Formulation

Based on the background, the subject matter of this research is how to increase quality of graduates using integration BPM and LSS especially in IE IP UII (Industrial Engineering International Program University Islamic Indonesia). There are some symptoms of quality that occur in IE IP UII such as students GPA below 3, student retention, and lateness graduation based on gap analysis in Figure 1.2. These symptoms can decrease the quality of graduates in order to meet requirements from stakeholder such as parents, employer and etc. Therefore, quality management is needed to improve quality of graduates. Furthermore, It needed to make business process management in order to sustain this quality improvement.

1.3. Research Question

This research will systematically collect and critically analyze the existing contributions to identify important factors to integrate these two methodologies and applied in Higher Education. Related to the purpose, main research question addressed in this review are:

1. How to utilize BPM & LSS methodology in Higher Education to increase quality of graduates?
2. What kind of solution that can be given to improve quality of graduates in Higher Education using those 2 integration methodologies?

1.4.Research Objective

Based on the research question above, this research is created to fulfill several objectives as mentioned below:

1. To develop a framework integration of BPM and LSS methodologies in higher education to improve quality of graduates.
2. To find and provide the best solution to existing problems so that higher education can improve the quality of graduates.

1.5. Research Limitation

Research limitation is a limitation of problems to make a border in the research to keep the research inside the scope. Based on the background, there are some scopes to make the research focus, as follows:

1. Case study is conducted at Universitas Islam Indonesia in Department Industrial Engineering International Program.
2. Important components of BPM that use in this research restrain only to the process modeling, do not include Web-enabled technologies, and business activity monitoring
3. The data used is the historical data from the student information system (UNISYS) and classified based on the Critical To Quality (CTQ) only for batch 2007-2010 and interviews to every process owner.
4. Not calculated the cost, so only uses 5W + 1H

1.6. Research Benefit

It is expected that by conducting this research, some benefits can be earned:

1. Understanding the attributes and parameters for generating BPM and LSS in higher education to improve quality of graduates.
2. Developing a framework of integrating BPM and LSS that implemented in Higher Education for further research.
3. To be the contributor in the development of knowledge.
4. Further research recommendation can be used for better future research.

1.7. Systematical of Thesis

Furthermore, this thesis writing will be continued as follows:

CHAPTER II LITERATURE REVIEW

This chapter will elaborate the inductive and deductive study. Inductive study is primarily important to determine the literature study of the previous research. Deductive study is elaborated to provide basic supporting theories to develop the integration methods.

CHAPTER III RESEARCH METHODOLOGY

This part explains how the research is conducted: about the method used, research object, how the data collected, and also provide the flowchart of the research steps.

CHAPTER IV DATA COLLECTING AND PROCESSING

This chapter will present the elaboration of whole DMAIC phases as a tools Lean Six Sigma integrated with Business Process Management and contains the data obtained during the research and how to analyze data. Data processing result is displayed either in the form of tables and graphs. Processing the data also includes analysis of the results obtained. In this section is a reference to the discussion of the results to be written in Chapter V.

CHAPTER V DISCUSSION

Chapter five is going to discuss the results of data processing and the analysis. Discussion will be presented the result of

compatibility with the objective of research so as to produce a recommendation.

CHAPTER VI CONCLUSION AND RECOMMENDATION

The final section will describe the overall conclusions from the results of study and the suggestion for the future research.

REFERENCES

APPENDICE

CHAPTER II

LITERATURE REVIEW

In this chapter, there will be elaborations of the literature studies that are in the form of inductive and deductive study. There will be also K – Chart to identify state of the art in this research. Inductive study is the previous study that will be the basic of research. While deductive study is the theoretical basis for supporting the problem solving in the research. Inductive study was obtained from the journal and proceeding is published periodically. While deductive study was obtained from the study of textbooks related to the theory.

2.1 Inductive Study

2.1.1 Review on Previous Research

Various studies of quality management in higher education have been done by previous researches. There are many methods that can be adapted to support quality management in higher education. Those methods can be adopted from manufacture method quality improvement that adapted to be suitable for higher education or method that developed by organization to ensure quality of higher education. In research (Eymen, Kara, & Aydo, 2016) that examined the situation of quality management in higher education institutions of developing country found that even though higher education institutions have progressed in their quality efforts in recent years, there is still a long way to go. Therefore, higher education needs a method that can accelerate this quality effort to catch up higher education in developed country. Quality can be achieved as outcome through increasing process performance. Quality and processes are very closely linked to each other. It is impossible to expect high quality end-results without understanding what needs to be done to get a desirable output from various inputs (Grzibowska & Islam, 2011).

According to (Edler, 1997) higher educational institutions consider similar like corporations and if business improvement methods work for corporations, they should also work for higher education. But, Edler also noted that there is a basic problem with applying corporate quality techniques to educational settings, specifically stating: 'although educational institution are corporate-like entities, the primary activity of these educational institution is teaching and learning which is not itself a business activity'. Unlike industry's production and consumption of products or service, teaching and learning are different. They not inherently involve the activity of buying and selling with implication cannot be torn apart into two halves: teaching on the one hand and learning on the other.

The process of teaching and learning is forced to conform to the company model when company quality improvement measures are employed across an educational institution as a whole. Thus, teaching and learning is forced to conform to the company model. Teaching and learning is turned into the "production of education" for business and is "driven" by considerations of efficiency, availability, technology, delivery, and marketability. The danger maybe is the wholesale reduction of educational values to corporate values. It is no longer an exaggeration to say that systems of education management are more important today than education itself (Edler, 1997).

Education management also must be faced greater pressure to be competitive with new forms of learning, new technologies for teaching, and new requirements for students' competences. Against this background, the need for educational organizations, including faculties, to carry out the market research and keep a close check on the quality is self-evident (Pavlović et al., 2014) .

"Quality" in general is defined as "the ability of a product or service to satisfy stated or implied requirements" According to (Stanislav & Willborn, 1997). Inherently, the requirements are sets by the customer. The product of universities are the students, or to be more precise, it is the knowledge, experience, skills and overall competence the student gains in the course of his/her studies. The requirements for a student's engineering knowledge, for instance, are sets by the companies he/she will work for, as well as government and professional institutions. Therefore, it can define the quality of education, regardless of the discipline of study, as "the ability of student's knowledge to satisfy stated requirements".

The requirements are set by customers of the university, namely employers, professional organizations, alumni, government and society as a whole, are then translated into programs and courses of study, much like in manufacturing, where a product briefly is translated into a set of design requirements. The university also sets certain requirements internally, in order to ensure that students have the required competence, or at least pass a sufficient number of course before they graduate (Stanislav & Willborn, 1997).

The difficulties in defining customer requirements, while there are variety of stakeholders (students, parents, employers, faculty members, government, and general society) that has different interests, are added to the complexity. This characteristic of higher education system, however, cannot overshadow the need for an operational definition of quality, one that provides a way for improvement. According to (Pryor et al., 2012), students are the ultimate stakeholders. They are customers, in-process material as they learn, co-managers of the teaching/learning process, and final products as they graduate and seek employment.

The systematic application of company assessment measures affect to educational institution reduced to a "production model" where the product is learning and everything else is considered as means of production. In defining learning as something done exclusively by the student and, in addition, in defining any help the student receives in learning as part of the support services provided to the student, teaching simply becomes another service the institution provides to help students learn. By separating teaching from learning and treating the former as means of production, the production model designates the managers of education as the organizers and decision-makers of educational work. Teaching becomes one of the many myriad functions of an organization that can be viewed according to Herbert Simon, as an information-processing machine (Edler, 1997).

Although in this model there are some similarities with a manufacturing system, the more humanistic nature of education makes it more complex. The dynamic interaction of teacher and students and the fact that products of the system themselves have direct effects on the process again, are among the reasons (Edler, 1997).

The influence of many academics are independent of the market while industry quality techniques often suggest studying the market (the real needs of customers) and focusing quality to meet these needs (Owlia & Aspinwall, 1997). Therefore, (Stanislav & Willborn, 1997) said that to provide confidence to their customers, the

students will have the required knowledge after graduation by ensuring that student knowledge meets customer specifications. This implies that both customers and specifications are known. Thus, the first step is to define who the customers really are. A survey from students, their families and alumni can be helpful. Certain policy issues should also be clarified by the faculty and staff. What do we want? Is research our strength, or is it curriculum, strong emphasis on teaching and leading-edge courses? What is our market? Should we attract students from our province/state/country, or should we focus more on international students? A number of universities and departments have gained excellent reputations by focusing on their strengths and defining their market niche (Pavlović et al., 2014).

High school graduates have to meet entrance requirements, such as a sufficient grade point average and a good score from the Scholastic Aptitude Test (SAT), in order to enroll at university. The university may even require prospective students to prove the ability for study in the chosen discipline by giving them an entrance exam. This is essentially an incoming inspection of a product. In the course of university studies, the student gains new knowledge, experience and skills. The attainment of competence is inspected in process at a course level, where the teacher tests the knowledge by using methods such as term tests, take-home assignments, surprise quizzes and final exams. It is also inspected at a program level, where the student's academic status is assessed, in terms of the number of courses passed and grades received. Graduation is possible only when the requirements set by the university are met. After graduation, the student's knowledge will be used by the employer or the student for his/her own purposes. Thus, employers and alumni, together with government and society as whole are the final customers of the university, who set the requirements for the quality of product. University students can provide useful information and feedback on the quality of teaching process, through course evaluations, surveys of student needs and experiences in terms of the learning environment (Stanislav & Willborn, 1997).

Universities should have a system in place for collecting and analyzing data from the prospective student employers, alumni, government, graduate schools and the community. The requirements of governmental and professional institutions should be defined, as well (Stanislav & Willborn, 1997).

The student as a virtue of the product to have no defects implies that all specifications are met. On the other hand, the term "zero-defect" has a different

meaning in different industries. In the electronic industry, the goal may be 1 part per million (ppm) defective, at most. Our carpenter will be satisfied with one in a thousand. Therefore, the universities should be able to say to their customers: “If you want our students to know how to use a manometer to measure relative pressure, we can assure you that 999 students out of a thousand will know that”. Or “At the most, one in every million students will not be familiar with the name of the first president of the United States”. Like zero-defect products, zero-defect students are not “perfect”, in the sense that they know everything. They just satisfy all the requirements. Also, not all quality characteristics are critical, example in case of not meeting the requirements, these characteristics would render the product unusable. The ability of the car to run is its critical quality characteristic. The ability of a medical doctor to diagnose illnesses is his or her critical characteristic. A structural engineer who does not know the principles of the strength of materials fails to meet a critical requirement and should not be allowed to practice. This is where all organizations, including universities, should strive to achieve the “zero-defect” goal first: what the customer deems important. At university, “zero-defect” goals can be set at different levels. For example, a professor may set a list of topic and skills that all students in his or her course must master before they pass the course. Or, a department can set zero defect objectives at an undergraduate or graduate program level (Stanislav & Willborn, 1997).

Therefore, educational institutions require an innovative supporting methodology which helps in improving the quality of processes pertaining to the important functions particularly teaching, research, and service (Shoeibi & Zahmatdoost, 2015). One of many innovative supporting tools which can help in improving the quality of process, pertaining to the important functions such as BPM (Business Process Management) and Lean Six Sigma (LSS). Lately, there is a trend in the research development to apply BPM or LSS methodology in Higher Education environment. However, the developing only focused for their own method instead of trying to develop integrating methodology between BPM and LSS. BPM can be a framework or guidance to apply LSS in higher education. By combining key concepts from LSS with the capabilities of BPM (including process modeling and analysis, automation, and executive dashboards that deliver real-time performance metrics to process consumers), a business can ensure that their people are focused on the most meaningful value-added work (Skalle & Schuster, 2008). According to (Redinius,

2010), If your organization has started with BPM before starting Six Sigma, BPM will help to identify the most beneficial reason to apply Six Sigma. This is because Process Management provides the identification of problematic areas of the business and incapable process outputs. It is on these "incapable" processes and process outputs that the power of Six Sigma is focused to achieve improvement.

(Mattila & Mattila, 2014) said that BPM is as much about people than it is about process. In this paper, BPM does not stand for technology tool or initiative for business processes. Instead, focus is in how to achieve a significant business process improvement in the context of a higher education institution and without technology. From this research, researcher concludes that BPM will keep the personnel motivated and enthusiastic. BPM is likely to lead to several benefits such as making conscious and systematic decisions based on strategy when planning operational actions, higher overall productivity, better documentation, operational model repeatability and transferability across organization and increase in efficiency on all levels.

(Reiner, 2012) has conducted project with the goal of this project is to analyze Business Process Management practices in higher education institutions, compare them with those in companies, prepare a process framework, and establish a consortium and a course for HEI management staff. The main results of Reiner showed that the following processes are not very mature among the research target group: communication processes, research processes, teaching / education processes, and marketing related processes including alumni relations. And for BPM framework, which development has already started, will serve as a central process landscape map for the HEIs, and will help various stakeholders (employees, students, professors) to have a clear overview of the processes on their HEIs.

In research (Pryor et al., 2012), Six Sigma methodologies are applied to university processes. Six Sigma team evaluated the course and curriculum approval process. Time for collecting data is an issue in an academic environment because the course and curriculum approval process usually occurs only once a year. To be successful in universities and colleges, Six Sigma and other improvement initiatives should be aligned with elements that are an integral part of their respective systems (e.g., accreditation efforts and/or institutional effectiveness departments which are responsible for data analyses and report submissions). Also, student should be involved in Six Sigma and other excellence initiatives. In order to improve student performance.

(Arafeh, 2016) used Six Sigma tools and methodology to improve student English language performance at elementary school. That project provided a good platform for introducing the Six Sigma DMAIC methodology and tools to improve performance and solve process problems in different departments in the school, in spite of the immense challenges faced when implementing the Six Sigma method successfully in an educational setting, one of which was that students were partially responsible for their own learning. (Mazumder, 2014) using six sigma tools such as statistical process control, lean manufacturing, failure mode and effects analysis can help in the development of sustainable higher quality educational process.

(Kukreja et al., 2009) provides a brief review of the quality improvement literature related to academia and a case study using Six Sigma methodology to analyze students' performance in a standardized examination. They found Six Sigma to be an effective tool for curriculum improvement and team building.

Six Sigma provides incremental improvement through its analytical abilities and is complemented by BPM which provides the data from the ongoing processes on a real time and Lean itself is a methodology that focuses on reducing cycle time and waste in process and industrial engineers see BPM as an opportunity to apply manufacturing optimization techniques in the context of organizations that deliver services rather than physical product (Skalle & Schuster, 2008).

Hence, from this inductive study, methods from manufacture quality improvement such as LSS can be adapted to be suitable for higher education to ensure quality of higher education. However, in order to face more humanistic nature of education (The dynamic interaction of teacher and students) that making it more complex, it needs BPM to be adapted in higher education to motivate and enthusiastic all stakeholder involved in higher education in order to conduct this LSS. Therefore, researcher tries to apply LSS and BPM as a means of drive quality and operational excellence in higher education system.

2.1.2 Position of Research

The position of this research will be determined by K – Chart based inductive and deductive study. K – Chart is a tool encompassing capabilities including clear organization and designation of issues under study, the methodologies adopted, the detail result expected presented in a simple way by use of a tree diagram (Zainuddin, 2006). The topic that will be discussed in this research is the continuous improvement quality output of Higher Education Institution using integration LSS and BPM to drive quality and operational excellence. Quality management is general issue that related to the topic above with focused in Higher Education system. Quality management has 4 main components: quality planning, quality assurance, quality control, and quality improvement. Operational aspect in higher education is divided to be 3 that are administration, education/instructional, and auxiliary. In education/instructional operation aspect has 3 issues that are program, students, and research. Methodologies that used to drive quality and operational excellence in higher education are TQM, Lean, Six Sigma, ISO 9001, BPM, MBNQA, APIC. It can be used to improve any performance parameters in higher education such as quality of student, service quality, quality of lecture, quality of curriculum, and so on. For the quality of student performance parameter has 4 possible design parameters that are employment, GPA, graduation, and retention student. In this research, researcher only focuses on GPA, graduation, and retention student because the complete data from the place study case conducted only given in that three design parameters.

In addition to improve the quality of student in performance parameter, researcher is using integration methodologies “lean six sigma” and “business process management”. Those two methodologies used to apply in manufacturing, hospitality, banks, and airlines. The researcher tries to apply this method to improve quality of student with the assumption that student as a raw material for university to become a product that can benefit for stakeholder. The whole process of knowledge based on development that has been elaborated in the K-Chart development in Figure 2.1 below:

CHAPTER III

RESEARCH METHODOLOGY

In this chapter, the steps for conducting the research are applied as a reference in order to keep focusing on the primarily goals, which are going to be achieved.

3.1 Objective & Location of Research

This research was conducted at Universitas Islam Indonesia (Department of Industrial Engineering International Program), located in Sleman Yogyakarta. Relevant literatures in this research are found by using electronic database that are Elsevier (sciencedirect.com) and Google Scholar. The object of this research is to increase the quality of graduates in higher education by improving business and education process.

3.2 Requirement of Data

3.2.1. Primary Data

The primary data are divided into several kinds of data that are needed for fulfilling the goal of the research. The primary data contain the result of interview from every process owner at Department International Program Industrial Engineering Universitas Islam Indonesia.

A. Interview Result

The interview is proposed to generate the information that cannot be acquired by direct observation as well as the historical data. The interview consists of several questions to understand the condition of education and business process.

B. Direct Observation

Direct observation was conducted based on personal experience of researcher as one of the students of the International Program, Department of Industrial Engineering Universitas Islam Indonesia. This experience data can be transformed to be information as idea to support problem formulation and problem solving in this research.

3.2.2. Secondary Data

The secondary data has already provided by the university, so those can be directly acquired. They presented in the form of the historical data in information system campus that will be used to conduct the statistical analysis in six sigma methodologies. The data consist of GPA, retention student, and graduation. The data will be implemented to analyze the capability process and sigma process.

3.3 Tools of Analysis

This research is using several tools in order to conduct the data processing, which are mentioned as follows:

1. Microsoft Excel®

This tool is mostly used for the calculation of the statistical analysis. The formula that used is basic formula that is provided by this software.

2. Microsoft Visio®

The tool is used to build Ishikawa diagram and swim lane diagram to analyze and improve the "As Is" process to increase level of sigma in process and capability.

3. Mendeley®

The tool is used to help making citation and reference with coordination to the database Mendeley into your library & extracts the metadata to create library. It collects and organizes citations then easily inserts them into documents & format bibliographies.

4. Signavio Process Editor®

The tool is used to help making process framework in web-based business process modeling tool. It helps to give process a shape to show the result of process identification.

5. SPSS®

SPSS® is a widely used program for statistical analysis in social science. Descriptive statistics application in SPSS® is used to test normality data sample.

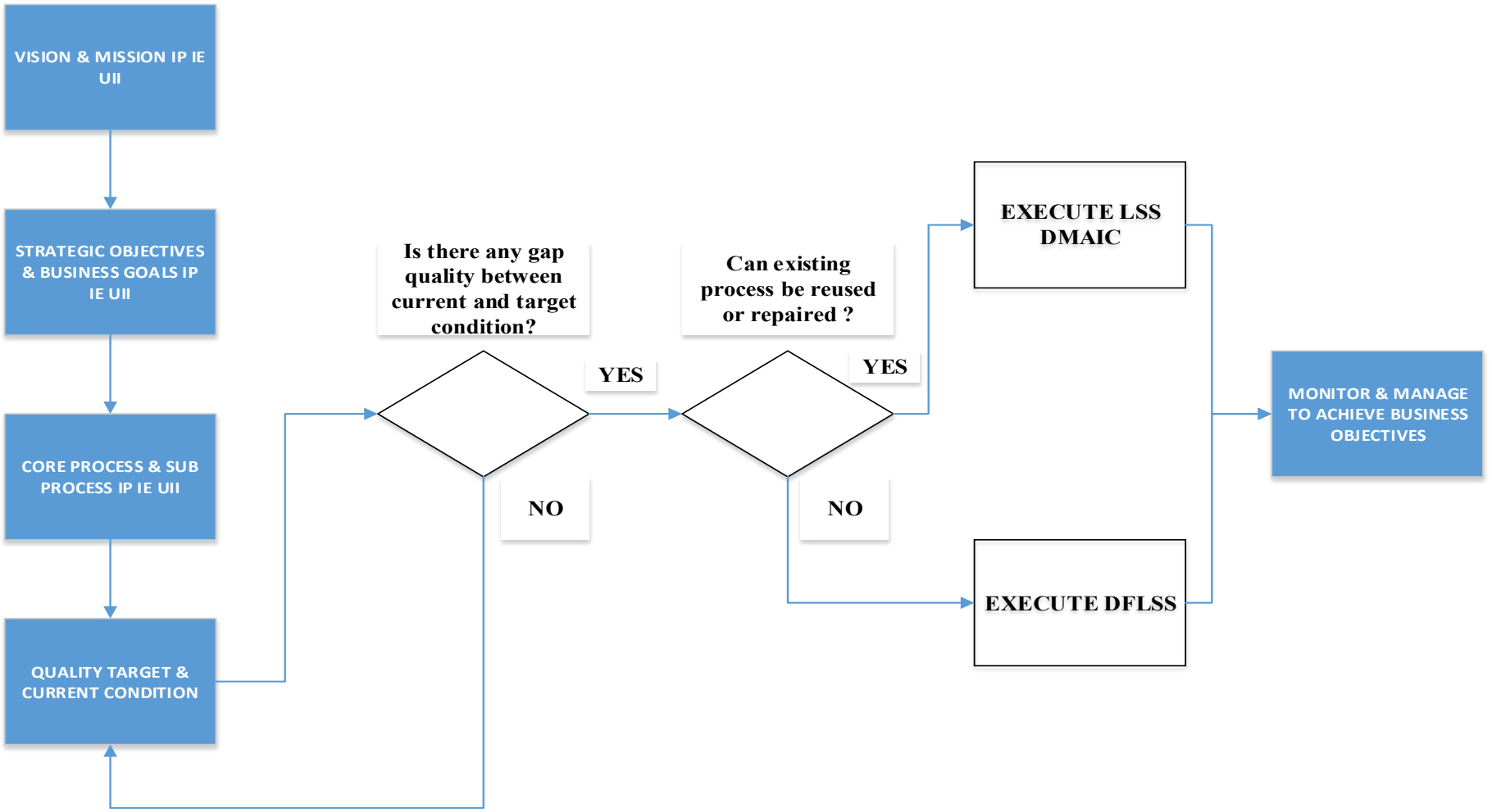
3.4 Key Success Factors

LSS achieves business transformation through the coordinated execution of multiple process improvement and design projects. There are three keys to success in this transformation:

1. Selection of the right projects for improvement or design
2. Execution of the projects by using methodologies embodied in LSS
3. Continual management of processes to achieve business strategies and goals

The first and third components are strategic in nature, where the second component is tactical. BPM capabilities, including modeling, simulation, and real-time control over processes, can play a significant role in enabling all three areas. Project selection by using a BPM framework provides sustainable improvement and results in the achievement of both short and long term strategic objectives and business goals.

This strategic objectives and business goals come from business vision and mission higher education itself. From this strategic objectives and business goals create core process and sub-process as a way to achieve it. Furthermore, identify quality target and current quality condition in every core process in higher education. If there is a gap between current and target quality then the most gap of quality core process will be focused to conduct this project LSS DMAIC. If process does not exist in higher education itself, then the project will use DFLSS (Design For Lean Six Sigma). After that, this project will be monitor and manage to achieve business objectives. Figure 3.1 shows Key Success Factor and how to relate vision and mission to this methodology.


VISION & MISSION IP IE UII
STRATEGIC OBJECTIVES & BUSINESS GOALS IP IE UII
CORE PROCESS & SUB PROCESS IP IE UII
QUALITY TARGET & CURRENT CONDITION
Is there any gap quality between current and target condition?
YES
NO
Can existing process be reused or repaired ?
YES
NO
EXECUTE LSS DMAIC
EXECUTE DFLSS
MONITOR & MANAGE TO ACHIEVE BUSINESS OBJECTIVES

CHAPTER IV

DATA COLLECTING AND PROCESSING

This chapter will elaborate the collection of the data as well the processing of the data using DMAIC phases. The data collection is divided into the primary data and the secondary data. Both of data was derived from direct observation, interview and historical data provided by the higher education. The data processing will be developed based on the methodology that has been built in the previous chapter.

4.1 Data Collection

4.1.1. Industrial Engineering Department University Islamic Indonesia International Program Profile

Department of Industrial engineering was founded in 19821, and since 2003 until today still has achieved A accreditation from the National Accreditation Board and has produced thousands of alumni who have worked in the private and public sectors. Industrial Engineering curriculum is designed based on system manufacturing and services that are suitable to the rapid development of information technology and global influence in human behavior and industry. The learning system of the Industrial Engineering program refers to the active learning that is supported by permanent and invited lectures, mostly educated S2 and S3 as the means to build a magnificent and comfortable teaching and learning atmosphere. Industrial Engineering has started developing International Program since 1999, which is a program of lectures that uses English as the language of instruction in all activities, both academic and non-academic activities.

The study program is designed to equip graduates of IP UII with theory and experience to perform experiments and laboratory work practices. The basic purpose of curriculum in Industrial Engineering study program is to equip students not just limited to science competence, but also make room for intellectual growth and maturity that is

based on Islamic values to support the development of professional competence and social responsibility. Students are educated to have an edge in understanding on the theory and practice experience and oriented to problem solving ability.

Industrial engineering program curriculum is designed based manufacturing system and services that are tailored to the rapid development of information technology and global influence human behavior and industry. Manufacturing system is elected as a model of learning due to the type and nature of the problems in system manufacturing can provide a fairly clear picture/ full of the concepts and applications of each of the main pillars (Production Engineering, Operational science, Ergonomics/Human Factor Engineering) as well as the functions of the three pillars mentioned. Based on this background, manufacturing system is an object of study in this Department of Industrial Engineering Faculty Technology Industry Universitas Islam Indonesia.

4.1.2 Vision

The establishment of leading Department of Industrial Engineering UII and able to produce graduates who are competent in the field of Industrial Engineering, noble, contribute to national development and able to take part in scientific development recognized in the international world.

4.1.3 Mission

1. To implement higher education that oriented to the development of science and technology.
2. To implement and produce the research activities that are beneficial to national development and contribute to the improvement of the quality internationally
3. To implement community service and da'wah islamiyah are beneficial to the progress of society.

4.1.4 Target

1. Industrial Engineering graduates are able in the planning, design, analysis, development, implementation and improvement of integrated industrial system based information systems.
2. The development of curriculum in accordance with the development of the industry
3. The development of conducive academic climate
4. To increase quality research activities and contribute to the development of science and technology
5. To increase ability of soft skills for graduates based treatise Islamiyah
6. To increase community service activities oriented industrial development for welfare of society
7. To increase quality of da'wah Islamiyah activities

4.1.5 Objective

1. Mastering the basic of scientific and technical skills in the field of industry to be able to find, understand, explain, and formulate ways of solving problems in industrial engineering
2. Being able to apply science and industrial engineering skills in productive activities and service to the society with Islamic attitudes and behavior in accordance with procedures set out in the life of Al-Quran and Hadith.
3. Being able to act and behave in the Islamic way in present himself working in the field of industrial engineering expertise and life together in society
4. Being able to follow the development of science and technology in the field of industrial engineering
5. Capable of independent spirit in their profession and have the entrepreneurial insight that can be useful for improving the welfare of society

4.1.6 Quality Target of Industrial Engineering University Islamic Indonesia

- Working within the first year at least 70%
- On time study of at least 80%

- Lecture performance value ≥ 3,00 (scale 0 until 4) at least 90%
- NKKU achievement index on the religion field ≥ 3,00 at least 90%
- The value worship practices with the results of "good" at least 90%
- Basic Leadership training Islamic values with the results of "good" at least 90%

4.1.7 Higher Education Process

Based on the collecting of data observation, documentation, and interview, education process that conducted by this higher education is divided to be several steps processing, that are:

1. Students Enrollment

In this higher education, to be admitted as an International Program Student, prospective students must pass the Admission Test organized by University Islamic Indonesia. There are 2 types of admission tests:

a. Computer-Based Test (CBT)

CBT is a selection test by using a computer. This selection test is open for those who are interested in most study programs at UII, except the medical study program.

b. Paper-Based Test (PBT)

PBT is a selection written test. This selection test is open for those who are interested in all study programs at UII. For the medical study program, the test is conducted in 2 sections.

c. Outstanding Student Tracking (Penelusuran Siswa Berprestasi, PSB)

PSB is a selection test by tracking outstanding students. This test is divided into 3 categories: outstanding students in academics, outstanding students in sport and arts, and outstanding students coming from less fortunate families.

- Outstanding Student in Academic Achievement

Student who has high academic achievement who has won certain science competitions at provincial, national, or international level can apply through this admission category.

- Outstanding Student in Sports and Arts

Students having achievements in sports and the arts either levels of province, national, or international can apply through this admission category.

- Outstanding Student Coming From Less Fortunate Families

Students, who are accepted through this admission category, will not be charged Catur Dharma fee and a tuition fee for 8 semesters. The students' achievement will be evaluated every semester. However, this scholarship will be stopped if the students fail to maintain their good achievement.

2. Course Enrollment

Before a semester start, each student must pay the tuition fees and enroll in courses of interest (key-in). The enrollment process includes the selection of courses and the registration for these courses through a key-in on the computer system. IP management appoints academic advisors to guide students in selecting appropriate courses taken for the semester. The time schedule for key-in is based on the academic calendar issued by university. If students cannot do the key-in at the scheduled time, they are allowed to ask for assistance from fellow student complete the key-in. A failure to meet the due date will result in a study leave. The enrollment procedures for first semester students are slightly different from those for students of the semesters.

University Islamic Indonesia applies a Semester Credit System (SCS). The application of the Semester Credit System helps students finish their study faster than the packaged system. In addition, it provides flexibility for students to take majors that meet their interest, talents, and capabilities, and to take different combinations of compulsory and elective course in one semester. The characteristics of the semester credit system are:

a. The academic load of each course is measured by Semester Credit Points (SCPs).
b. The SCPs for each academic activity vary depending on how many hours it takes per week.

- A two-credit subject must be formally administered once a week in 100 minutes for a meeting in the classroom.
- A three-credit subject must be provided twice a week in the class in 150 minutes: 100 minutes for first session and 50 minutes for another meeting.
- A four-credit subject should be given twice a week in 100 minutes for each session.

c. Academic activities consist of compulsory and optional activities. The compulsory activities have to be attended by all students at a certain level, whereas, optional activities are provided to accommodate different interests, talents, and skills of students.
d. The maximum allowable SCPs for students in a certain semester depend on their academic performance in the previous semester.
e. Up to that maximum limit, students are free to determine the number of SCPs for each semester and plan the length of study based on their capability.

An undergraduate degree or Sarjana (S1) degree will be granted to students who have completed all categories of courses. There are five categories of courses, namely Character Development Courses (CDCs), Professional Ethics Courses (PECs), Knowledge and Skill Development Courses (KSDCs), Professional Courses (PCs), and Society Development Courses (SDCs). The detailed descriptions of each category are as follows:

a. CDCs consist of courses derived from the National Curriculum aimed at equipping students with sound personalities, attitudes, and behavior, so that they are well prepared for the real social life. There are 12 SCPs needed for Industrial Engineering students to accomplish this category courses.
b. KSDCs embrace courses, whose main objective is to lay the foundation for developing skills essential for professional or further academic purposes. There are 51 SCPs needed for Industrial Engineering students to accomplish this category courses.
c. PCs consist of courses mainly intended to equip students with a thorough understanding of analytical tools in a specific area of study. There are 47 SCPs needed for Industrial Engineering students to accomplish this category courses.

d. PECs refer to a group of courses derived from the curriculum of University Islamic Indonesia, whose main objective is to build intellectual and moral integrity among students. There are 30 SCPs needed for Industrial Engineering students to accomplish this category courses.

e. SDCs are courses among which students will choose as their area of specialty. There are 4 SCPs needed for Industrial Engineering students to accomplish this category courses.

3. Academic Activities

Academic activities is conducted suitable with courses schedule that student take when courses "key-in" that student take in every beginning semester. If the student takes courses with the academic loads are 24 credits then the student in 1 week must be:

- Study in class for 1,200 minutes.
- Do assignment for 1,200 minutes.
- Independent learning for 1,200 minutes.

Every student must follow lecture in class at least 75% from the number of meetings that have planned. In every semester is conducted evaluation 3 times that are:

- Midterm Exam (UTS)
- Final Exam (UAS)
- Remedial

Every exam only conducted once according to predetermined schedule and no supplementary exam in any form. The requirement to be able to follow UAS, every student must attend lecture at least 75% of lectures given by lecturers. It also applies for remedial.

Examinations are intended to evaluate students' progress and to form an integrated part of the quality control process of the university graduates. In addition to written exams, a lecture can assign an oral exam, assignments, seminar, papers, quizzes, reports

and the like. The percentage of mid and final examination and assignment to contribute to final marks will depend on the lecturers.

The issuance of a final grade concludes an academic process for a particular course during one semester. The final grade is granted by a lecture based on the weights of its components: mid semester exam grade, final exam grade, assignment grade, class participation., class presentation, and other activities specified by the lecture. The final grade is expressed in letters and each has its own value weight.

If students feel unsatisfied with the grades they obtain, they can complain to the lecturer within one week after the release of the grades. The students have to fill in the form of complaint provided by the IP, and will be responded at a maximum of 5 days.

Students can also open information technology support in Universitas Islam Indonesia called UNISYS. UNISYS is a web-based service where students can access their personal information and study progress. All UII students are given a special account to access this service. Username and password of the account can be seen on a letter received by students after their registration. In the UNISYS, student can access: database, status, concentration, schedule, attendance, study progress per semester, cumulative study progress, GPA, tuition fee payment schedule, Catur Dharma payment, other payments, and study leave.

Each academic year consists of the odd semester commencing in August and the even semester commencing in early February. In order to graduate, students must successfully accomplish a total of 144 SCPs academic credits load for Industrial Engineering within at least seven semester.

4. Graduation

To graduate from the IP, Department of Industrial Engineering's students must write a thesis. The requirements for writing a thesis are as follows:

- Students must have taken all required subjects and GPA not less than 2.00
- Students should pay the thesis supervision fee determined by the department.
- Students is not taking a leave during the thesis writing
- Students must have conducted internship
- Students must have conducted community service (KKN)
- Students must have not fewer than 2 subjects to be taken

- Students pay the thesis fee and fill in the form of study plan

The maximum period for completing a thesis is 6 months starting from the date the letter of permission is issued. All students must sign the *'Rights and Obligations for Thesis Writing'* available from IP management encompasses the responsibilities of students, IP management, language and content advisers during consultation period. If students cannot complete their thesis within the second normal completion time (the second six months), their thesis is considered void and is given a fail grade. If they wish to write another thesis, they must follow the normal procedures starting from the beginning. The student' graduation standing is determined at the end of their academic period. Cumulative GPA at the end of the academic period determines one of the graduation standings. Universitas Islam Indonesia recognizes three different levels of graduation standings, namely:

- CGPA = 2.50 – 2.75 for satisfactory
- CGPA = 2.76 – 3.50 for with distinction
- CGPA = 3.51 – 4.00 for cum laude

4.2 Data Processing

4.2.1 Process Identification

Process identification is a set of activities aiming to systematically define the set of business processes of a company and establish clear criteria for prioritizing them. The output of process identification is a process architecture, which represents the business processes and their interrelations. Process architecture serves as a framework for defining the priorities and the scope of process modeling and redesign projects (Dumas et al., 2013).



Figure 4.1 IP IE UII Process Frameworks

From the Figure 4.1 above, the researcher designates Department of Industrial Engineering in Universitas Islam Indonesia Indonesia process consists of 5 key process areas that are teaching process, studying process, research process, development process, and management & supporting process and all of this key process areas have sub process. 4 of 5 key processes areas are core processes cover the essential value creation of a company, that is, the production of goods and services for which customers pay. Support processes enable the execution of these core processes. And management processes as a means to synergize all processes to improve the result and core process.

In evaluation phase, not all processes are equally important and not all processes can receive the same amount of attention. Various criteria have been proposed to steer this evaluation. The most commonly used ones are Importance, Dysfunction, and Feasibility. To determine these criteria, an organization needs information that has quantitative insight into the performance of their individual processes. In place of this case, researcher use UNISYS as a basis of information quantitative insight into the performance of their individual processes. The weakness of using this UNISYS as information quantitative insight is this information not cover all process that researcher identification before.

For the sustainable improvement, it needed to determine performance metrics for all process. This process performance metrics can be used as a basis for compensation, advancement and project LSS. This process identification helps LSS team in define and measure phase. LSS team can focus to a project that has significance influence to improvement in industrial engineering department with a holistic view. Hence, there are a balancing in allocation budgeting and this project do not disturbing another aspect in improving quality and process in higher education.

4.2.2 Identification of Wastes

At this stage, researcher tries to find solution in order to fulfill this gap current condition with target condition by reducing wastes in process education. The waste that has been identified will be eliminated. The gap between current and target condition will be expected to be reduced. Figure 4.2 shows the gap current and target condition with 3 symptoms of conditions that are GPA above 3, on time study, and student retention.

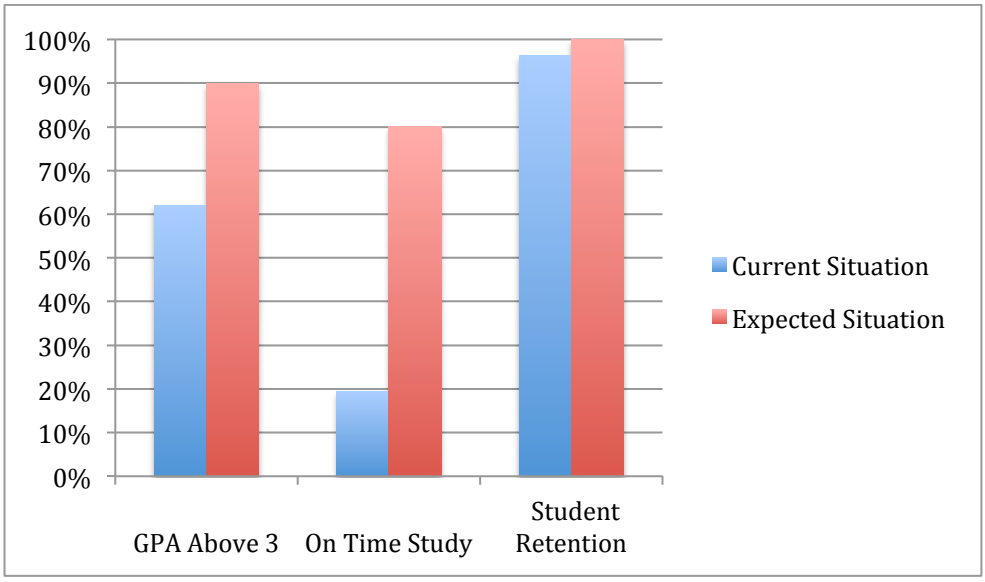


Figure 4.2 Gap Analysis IP IE UII from batch 2007 - 2012

Table 4.1 below shows seven basic types of waste in education process in order to reduce gap quality from IP IE UII batch 2007-2012. There are many solution in order to reduce the gap quality in Figure 4.2 above, one of many is using elimination of waste to get efficiently process or task in education process without decreasing the quality of graduates itself.

Table 4.1 Seven basic types of waste in education process in order to reduce gap quality IP IE UII batch 2007-2012

waste	Definitions	Elimination of waste
Defects	Wrong teaching plan and classroom schedule, mistakes upon registering for exams, failed exams, withdrawing from exams, incomplete or incorrect information	Create a check list to define "what is good" in the curriculum, announce student requirements, following and application of modern curriculum in the world, classroom schedules and timetable must be displayed and accessible to students and professors in a visible place.

Buffer stocks	Students who are left back, great variation in the number of passed exams in different exam periods, unnecessary and redundant parts of curriculum	Regular student attendance at lectures and practice classes, introducing obligations and manner in which exams are taken to students at the beginning of each semester, taking exams during the semester through mid-term tests, project tasks, and term papers.
Motion	Students moving from classroom to classroom, not getting the information on: taking exams and mid-term tests, exam periods and registration, mistakes upon registration	Conducting teaching in a single classroom, designing web portals and displaying information regarding exams and mid-term tests in one spot and on one notice board.
Waiting	Information (in exams, mid-term tests, exam periods), waiting to enrol in the next year, students and professors being late for lectures and practices classes, waiting for and replacing equipment necessary for teaching.	Faster information update, regular student and professor attendance at lectures and monthly checks of student attendance, student surveys in the work of professors and assistants.
Transportation	Students passing from year to year, information transfer from the student service to the notice board regarding exams and mid-term tests.	Designing web portals and displaying all information in one spot and on one notice board.
Overprocessig	Re-taking exams, re-enrolment, re-taking classes	Implementation of the new process
Overproduction	Excessive number of students who did not find a job within six months of graduation	Cooperation of the Faculty with organizations and companies, giving presentations – career days, organizing employment fairs.

4.2.3 Define

Define is initial stage of sequence DMAIC phases. Define phase is conducted to translate and define the problem. In this study, the tools that used are SIPOC, CTQ (Critical To Quality). SIPOC used to view the process flow that occurs in the company today, where the process here involves Supplier-Input-Process-Output-Control. Figure 4.2 shows SIPOC diagram in higher education.

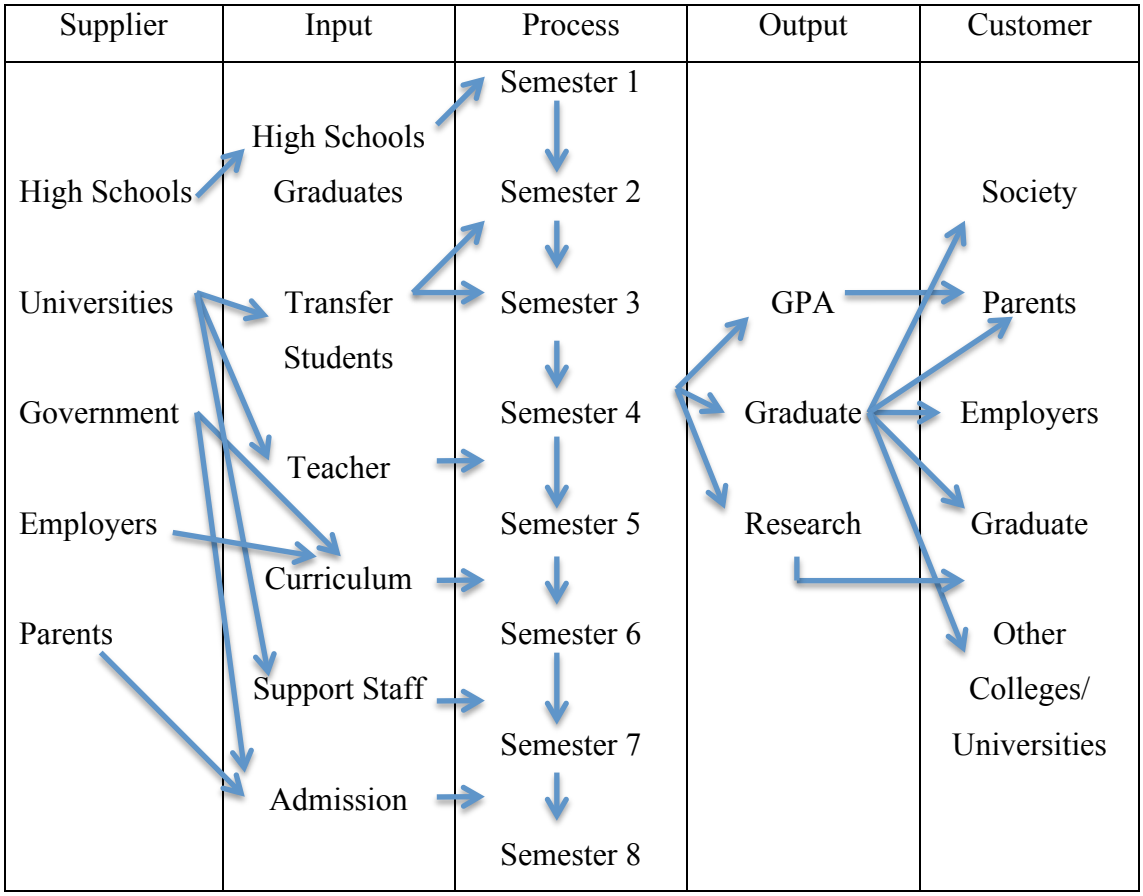


Figure 4.3 SIPOC in Industrial Engineering Department International Program UII

SIPOC above is useful in describing the interactions that occur between processes with elements that are beyond the technical process of service, such as supplier (High Schools), the input (High Schools Graduates, Transfer Students, Teacher, Curriculum, Support Staff, and Admission), output (Graduate, Research) and customer (Society, Employers, Graduate, and school).

After mapping SIPOC that took place at the Department of Industrial Engineering, then compiled CTQ (Critical to Quality) to determine the factors that measures how the quality and characteristics desired. This CTQ in student graduates of Industrial Engineering Department determined based defect or level of fail student from the results of students get and done through the requirement in every semester. Identification is conducted against the criteria of quality characteristics that have the potential to cause bad quality of graduates. There are many critical potential to cause bad quality of graduates. But, because of the availability data that can be tracked by information system in this higher education, researcher state that critical potential to cause bad quality of graduates are student retention, GPA below 3, and lateness graduation. Table 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, below are amount of student Industrial Engineering Department IP UII batch 2007 – 2012 and attribute data CTQ quality of graduates.

Table 4.2 Amount of Student IE IP UII of batch 2007 – 2012

Batch	Amount of Student IP FTI UII	Total
2007	22	113
2008	13	
2009	20	
2010	15	
2011	23	
2012	20	

Table 4.3 Attribute Data CTQ Quality of Graduates Batch 2007

Semester	Batch	Retention Students	Graduation	GPA below 3	Students fails
1	2007	21	0	14	15
2		21	0	11	12
3		22	0	7	7
4		22	0	9	9
5		22	0	13	13
6		22	0	11	11
7		22	0	8	8
8		21	4	11	18

Table 4.4 Attribute Data CTQ Quality of Graduates Batch 2008

Semester	Batch	Retention Students	Graduation	GPA below 3	Student fails
1	2008	13	0	7	7
2		13	0	8	8
3		13	0	2	2
4		13	0	3	3
5		13	0	2	2
6		13	0	7	7
7		13	0	1	1
8		7	2	3	9

Table 4.5 Attribute Data CTQ Quality of Graduates Batch 2009

Semester	Batch	Retention Students	Graduation	GPA below 3	Student fails
1	2009	20	0	7	7
2		19	0	10	11
3		19	0	11	12
4		18	0	10	12
5		17	0	5	8
6		16	0	6	10
7		17	0	4	7
8		15	2	3	15

Table 4.6 Attribute Data CTQ Quality of Graduates Batch 2010

Semester	Batch	Retention Students	Graduation	GPA below 3	Student fails
1	2010	15	0	2	2
2		15	0	7	7
3		14	0	4	5
4		13	0	6	7
5		13	0	2	2
6		13	0	4	4
7		13	0	8	8
8		5	1	2	12

Table 4.7 Attribute Data CTQ Quality of Graduates Batch 2011

Semester	Batch	Retention Students	Graduation	GPA below 3	Student fails
1	2011	23	0	14	14
2		23	0	12	12
3		21	0	10	12
4		23	0	7	7
5		22	0	13	13
6		22	0	4	4
7		22	0	3	3
8		5	1	2	12

Table 4.8 Attribute Data CTQ Quality of Graduates Batch 2012

Semester	Batch	Retention Students	Graduation	GPA below 3	Student fails
1	2012	20	0	14	14
2		19	0	7	8
3		19	0	7	7
4		19	0	12	12
5		19	0	10	10
6		19	0	8	8
7		19	0	4	4
8		15	2	7	17

The data were obtained from information technology service UNISYS. UNISYS is a website that provides student academic information and is also used to key-in KRS will students encounter every semester. From this UNISYS, the researcher elaborates information to extract data that can be used as CTQ. This process of data collecting is helped by front office to access account of the past student with permission from Dean Industrial Engineering Department International Program UII. Figure 4.3 below shows display of UNISYS website and information student academic that has been through by student in the past.

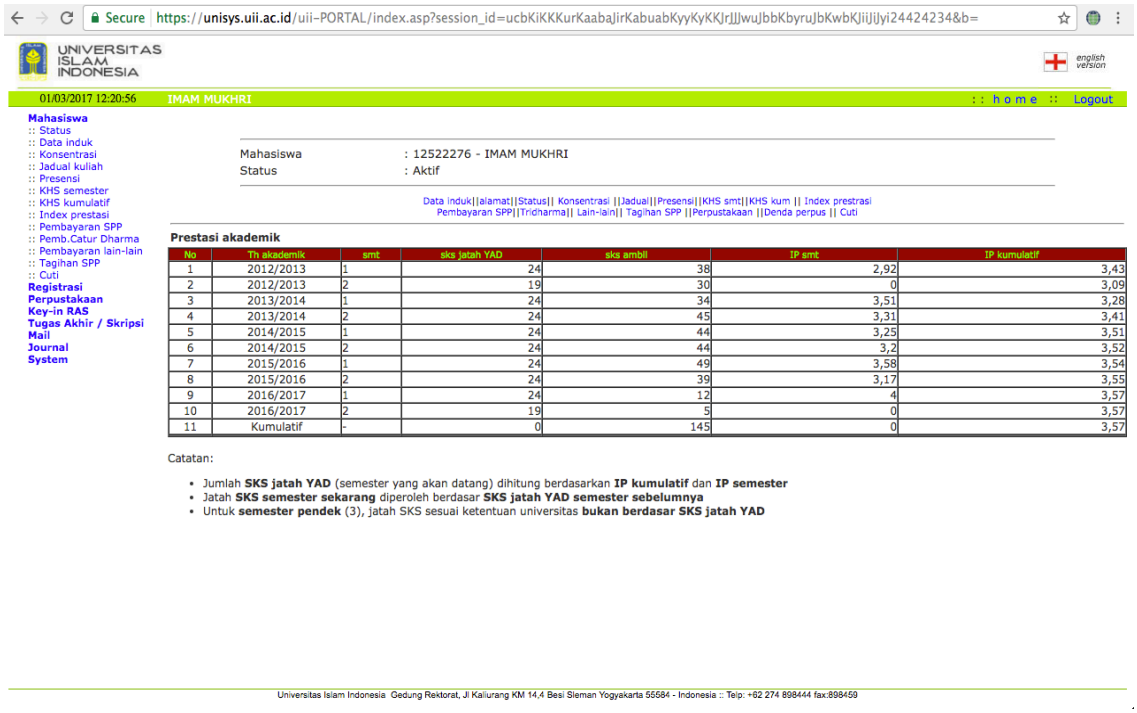


Figure 4.4 Display of Information Student that UNISYS Given

Retention data are obtained from the students' GPA student elaboration. If the value GPA is 0 so that, researcher assumes that the student does not follow complete process of education. For the graduation data, they are elaborated from the last update academic achievement in UNISYS. If the last update on academic achievement stated that the student has exceeded 8 semesters, then the student will be assumed as defect. In GPA below 3, the researcher elaborates the students' GPA from all completed semester. But, the result of remedial academic achievement in every 2 semesters does not include (excluded) by the researcher regarding that remedial as a rework in industry.

4.2.4 Measure

Measure is the stage for measuring the current conditions related to the process in Industrial Engineering Department. The measurement process is performed to measure the condition of the system related to the fulfillment of the CTQ have been set at the previous stage. Pre-processing is done by measure the number and percentage of defects that occur each semester. Defect is defined as the result of any process that does not meet provisions of CTQ's. Before the data is processed further, normality test of sample data must be done first. Normality test is performed to ensure normal distribution of sample data. To facilitate its implementation, the normality test is done with the help of SPSS software. Here is a graph of test result of normality of sample data from batch 2007 – 2012.

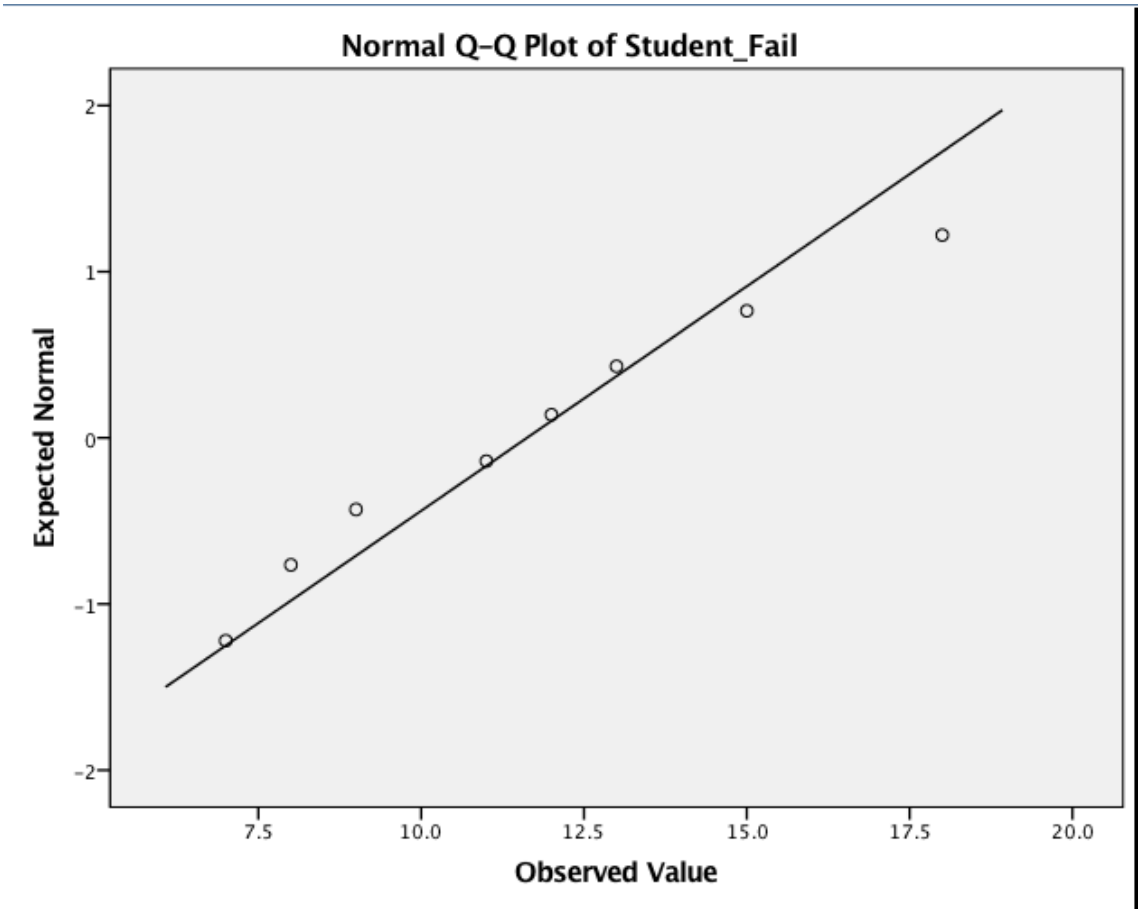


Figure 4.5 The result of normality test batch 2007 IP IE UII in Q-Q plot

The normal Q-Q plot is an alternative graphical method of assessing normality to the histogram and is easier to use when there are small sample sizes. The scatter should lie as close to the line as possible with no obvious pattern coming away from the line for the data to be considered normally distributed. From figure 4.4, sample data quite normal because the scatter data lie quite close to the line.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Student_Fail	.136	8	.200*	.967	8	.870

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Figure 4.6 Tests of Normality batch 2007 sample data IP IE UII

From figure 4.5, the sample size is 8. Therefore, Shapiro-Wilk test should be used. For the approximately normally distributed data, p = 0.870, so the null hypothesis is retained at the 95% level of significance. Therefore, normality can be assumed for this data set and, provided any other test assumptions are satisfied, an appropriate parametric test can be used.

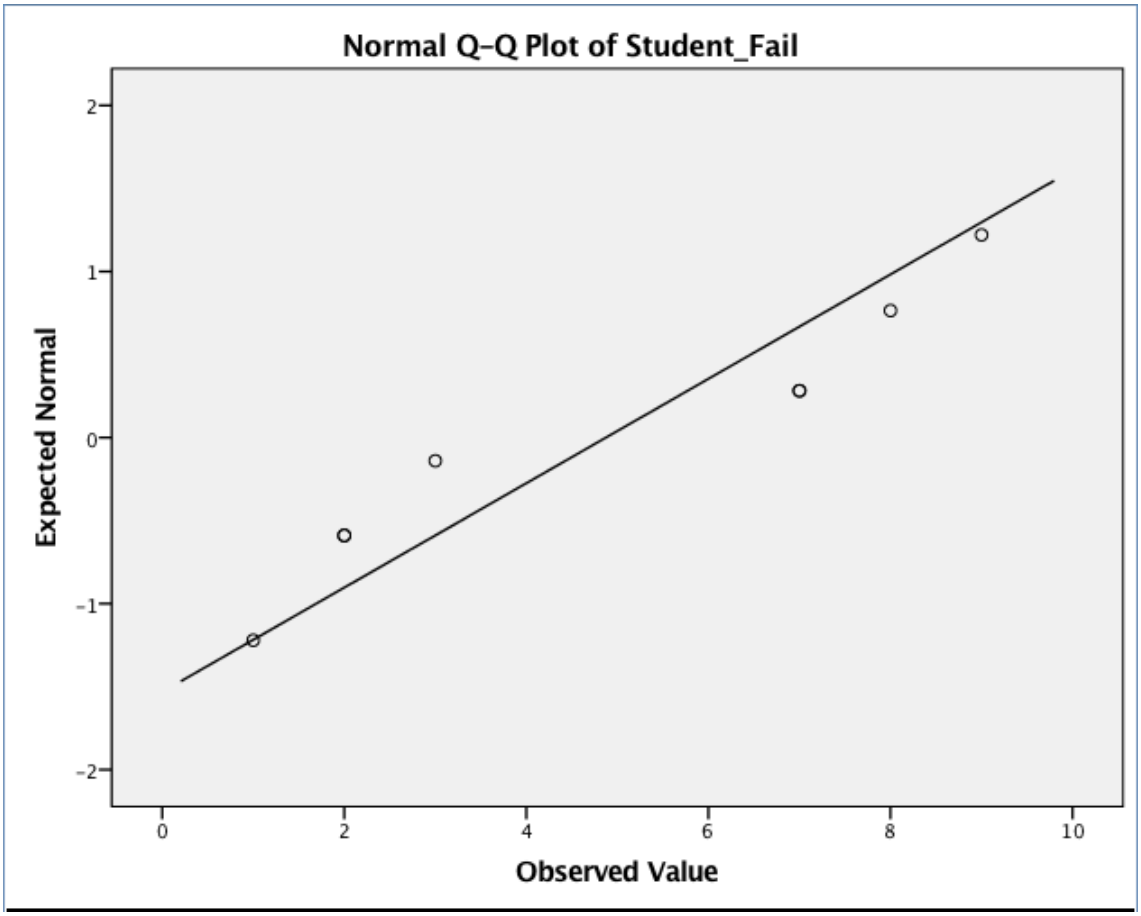


Figure 4.7 The result of normality test batch 2008 IP IE UII in Q-Q plot

The normal Q-Q plot is an alternative graphical method of assessing normality to the histogram and is easier to use when there are small sample sizes. The scatter should lie as close to the line as possible with no obvious pattern coming away from the line for the data to be considered normally distributed. From figure 4.6, sample data quite normal because the scatter data lie quite close to the line.

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Student_Fail	.248	8	.160	.867	8	.141

Figure 4.8 Tests of Normality batch 2008 sample data IP IE UII

From figure 4.7, the sample size is 8. Therefore, Shapiro-Wilk test should be used. For the approximately normally distributed data, p = 0.141, so the null hypothesis is retained at the 95% level of significance. Therefore, normality can be assumed for this data set and, provided any other test assumptions are satisfied, an appropriate parametric test can be used.

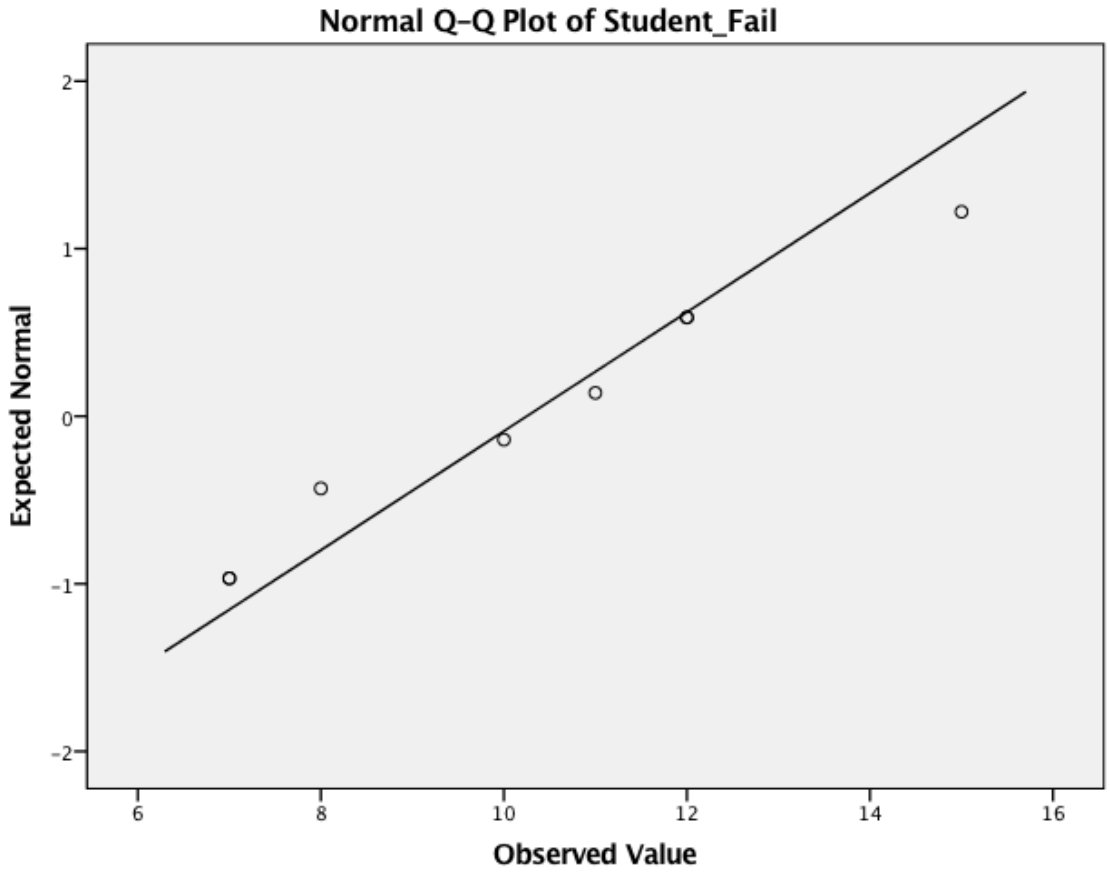


Figure 4.9 The result of normality test batch 2009 IP IE UII in Q-Q plot

The normal Q-Q plot is an alternative graphical method of assessing normality to the histogram and is easier to use when there are small sample sizes. The scatter should lie as close to the line as possible with no obvious pattern coming away from the line

for the data to be considered normally distributed. From figure 4.8, sample data quite normal because the scatter data lie quite close to the line.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Student_Fail	.163	8	.200*	.929	8	.503

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Figure 4.10 Tests of Normality batch 2009 sample data IP IE UII

From figure 4.9, the sample size is 8. Therefore, Shapiro-Wilk test should be used. For the approximately normally distributed data, p = 0.503, so the null hypothesis is retained at the 95% level of significance. Therefore, normality can be assumed for this data set and, provided any other test assumptions are satisfied, an appropriate parametric test can be used.

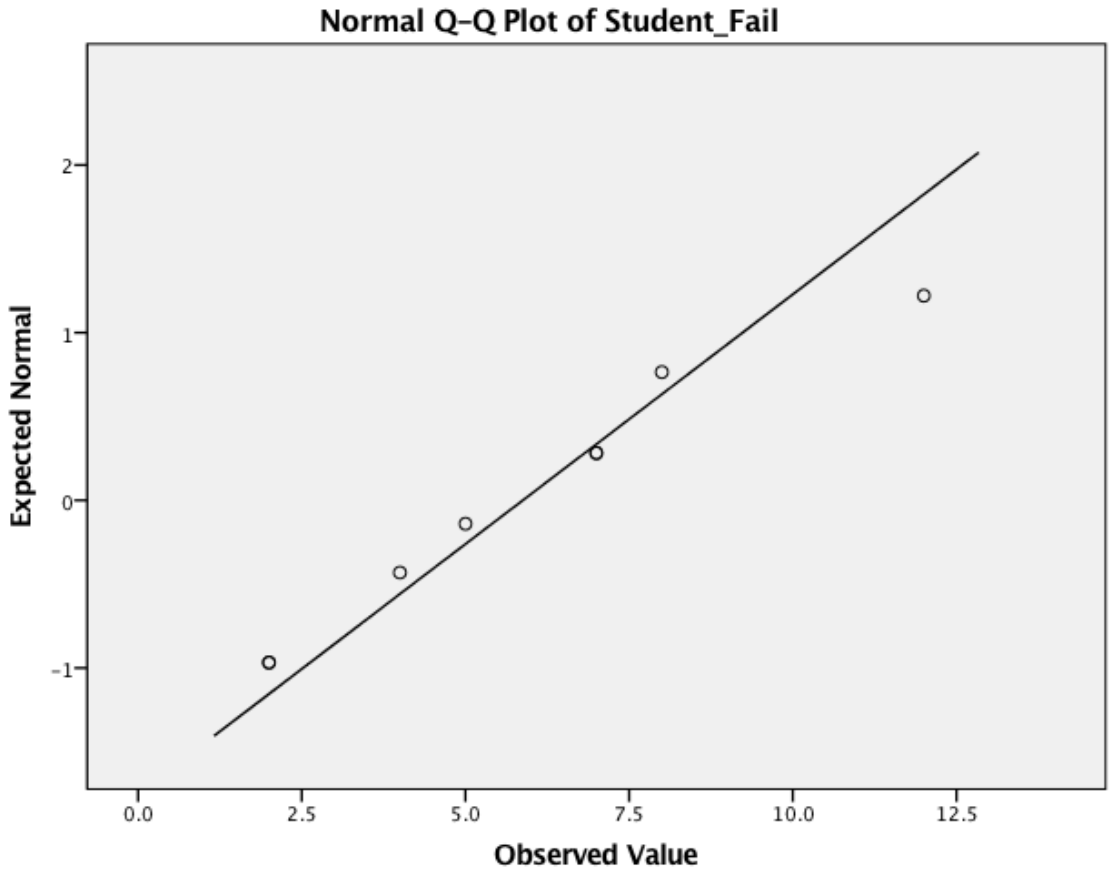


Figure 4.11 The result of normality test batch 2010 IP IE UII in Q-Q plot

The normal Q-Q plot is an alternative graphical method of assessing normality to the histogram and is easier to use when there are small sample sizes. The scatter should lie as close to the line as possible with no obvious pattern coming away from the line for the data to be considered normally distributed. From figure 4.10, sample data quite normal because the scatter data lie quite close to the line.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Student_Fail	.138	8	.200*	.935	8	.561

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Figure 4.0.12 Tests of Normality batch 2010 sample data IP IE UII

From figure 4.11, the sample size is 8. Therefore, Shapiro-Wilk test should be used. For the approximately normally distributed data, p = 0.561, so the null hypothesis is retained at the 95% level of significance. Therefore, normality can be assumed for this data set and, provided any other test assumptions are satisfied, an appropriate parametric test can be used.

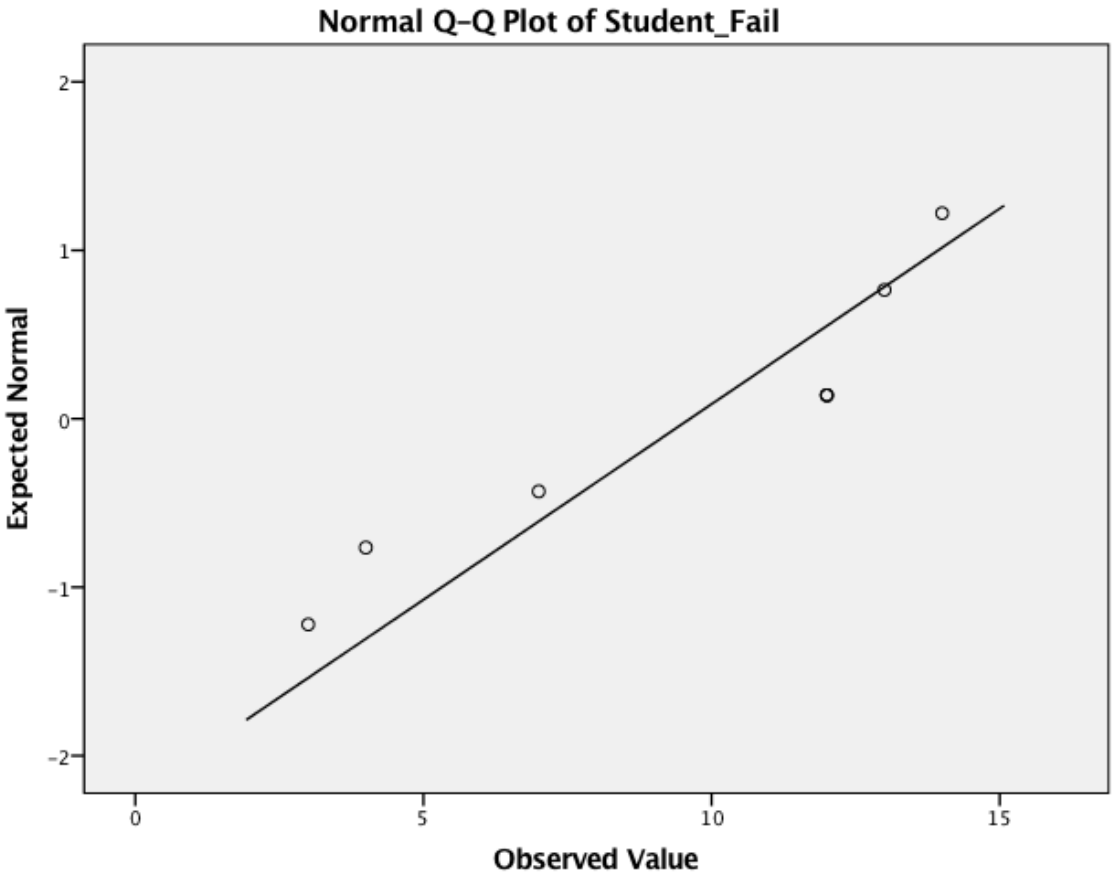


Figure 4.13 The result of normality test batch 2011 IP IE UII in Q-Q plot

The normal Q-Q plot is an alternative graphical method of assessing normality to the histogram and is easier to use when there are small sample sizes. The scatter should lie as close to the line as possible with no obvious pattern coming away from the line for the data to be considered normally distributed. From figure 4.12, sample data almost not quite normal because the scatter data lie not quite close to the line.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Student_Fail	.334	8	.009	.829	8	.058

a. Lilliefors Significance Correction

Figure 4.14 Tests of Normality batch 2011 sample data IP IE UII

From figure 4.13, the sample size is 8. Therefore, Shapiro-Wilk test should be used. For the approximately normally distributed data, p = 0.058, so the null hypothesis is retained at the 95% level of significance. Therefore, normality can be assumed for this data set and, provided any other test assumptions are satisfied, an appropriate parametric test can be used.

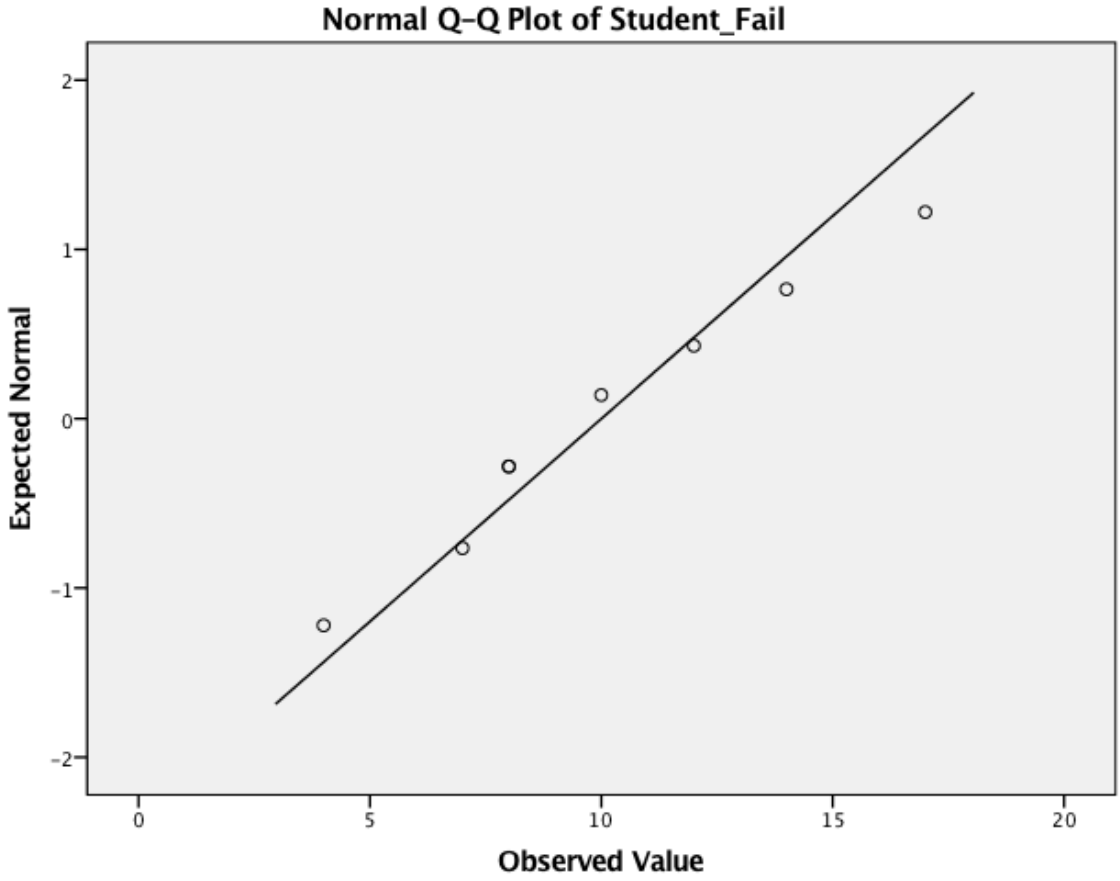


Figure 4.15 The result of normality test batch 2012 IP IE UII in Q-Q plot

The normal Q-Q plot is an alternative graphical method of assessing normality to the histogram and is easier to use when there are small sample sizes. The scatter should lie as close to the line as possible with no obvious pattern coming away from the line

for the data to be considered normally distributed. From figure 4.14, sample data almost not quite normal because the scatter data lie not quite close to the line.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Student_Fail	.184	8	.200*	.973	8	.918

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Figure 4.16 Tests of Normality batch 2012 sample data IP IE UII

From figure 4.15, the sample size is 8. Therefore, Shapiro-Wilk test should be used. For the approximately normally distributed data, p = 0.918, so the null hypothesis is retained at the 95% level of significance. Therefore, normality can be assumed for this data set and, provided any other test assumptions are satisfied, an appropriate parametric test can be used.

After the data sample is declared normal, then performed process capability. The proportion of defects use to determine the level of the upper control limit, mean and lower control limit, by creating a p Control Charts, the following is a p Control Charts each semester for data defect of the students in batch 2007 and 2012:

Table 4.9 p Control Charts – Batch 2007

Semester	Batch	Inspected Students	Students Defect	Defects Percentages	LCL	CL	UCL
1	2007	22	15	0.681818182	0.209124641	0.528409091	0.84769354
2		22	12	0.545454545	0.209124641	0.528409091	0.84769354
3		22	7	0.318181818	0.209124641	0.528409091	0.84769354
4		22	9	0.409090909	0.209124641	0.528409091	0.84769354
5		22	13	0.590909091	0.209124641	0.528409091	0.84769354
6		22	11	0.5	0.209124641	0.528409091	0.84769354
7		22	8	0.363636364	0.209124641	0.528409091	0.84769354
8		22	18	0.818181818	0.209124641	0.528409091	0.84769354
Total		176	93	4.227272727			
Mean		22	11.625	0.528409091			
NP Bar		11.625					

From the calculation of the upper control limit, mean, and lower control limits on Table 4.9 above, it may be graphed p Control Charts to determine whether the data is statistically under control or not, is as follows:

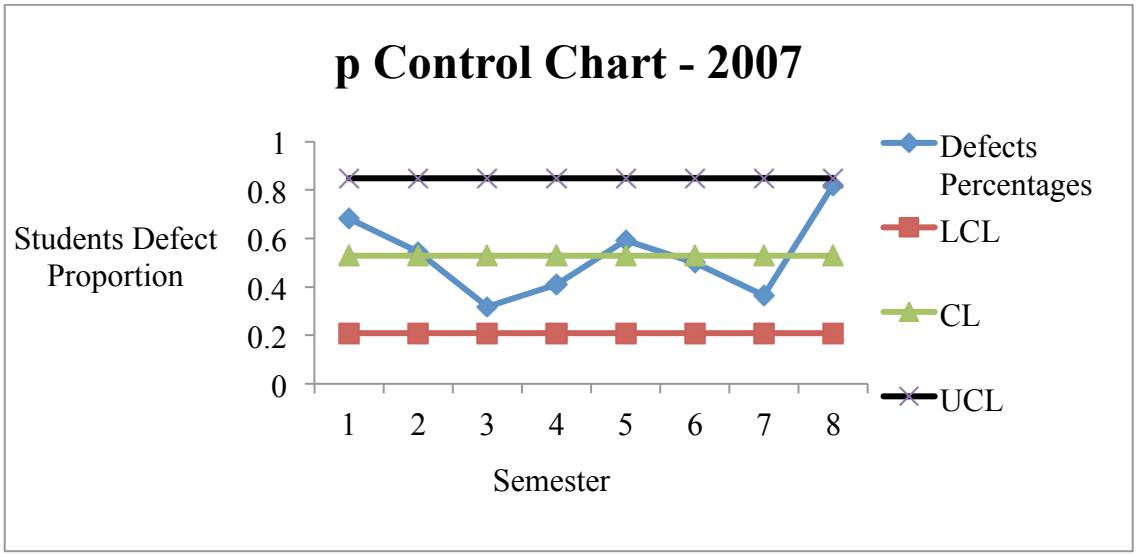


Figure 4.17 p Control Chart – Batch 2007

It can be seen from Figure 4.4 above, p control chart in batch 2007 shows the proportion of defects in statistical control. After calculating the p control chart and the result in statistical control, then the next calculation is DPMO level and sigma capability to know how big the quality of the International Program Industrial Engineering Program UII graduates. The following Table 4.9 is a calculation of DPMO and capability sigma:

Table 4.10 Calculation of DPMO & Sigma Level – Batch 2007

Semester	Batch	Inspected Students	Students Defect	Defects Percentages	DPO	DPMO	SIGMA
1	2007	22	15	0.681818182	0.340909091	340909.0909	1.909983322
2		22	12	0.545454545	0.272727273	272727.2727	2.104585347
3		22	7	0.318181818	0.159090909	159090.9091	2.498201172
4		22	9	0.409090909	0.204545455	204545.4545	2.325494491
5		22	13	0.590909091	0.295454545	295454.5455	2.037519106
6		22	11	0.5	0.25	250000	2.17448975
7		22	8	0.363636364	0.181818182	181818.1818	2.408457869
8		22	18	0.818181818	0.272727273	272727.2727	2.104585347
Process		22	11.625	0.528409091	0.247159091	247159.09	2.19541455

Here is a chart of the results calculation of DPMO and Sigma Level:

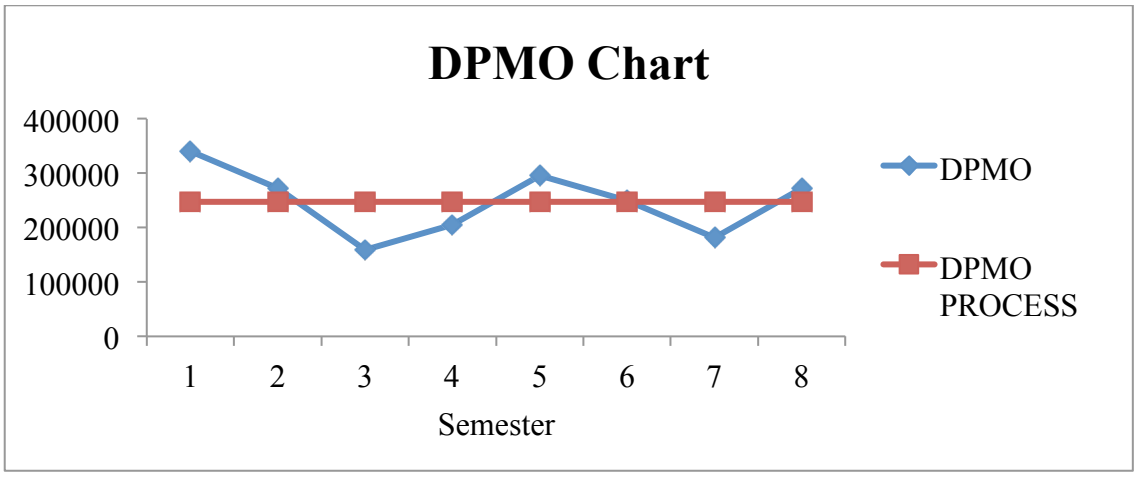


Figure 4.18 DPMO Level Chart

It can be seen from Figure 4.5 above, that the chart patterns of DPMO student defect shows varying results, due to the pattern of ups and downs of the value of the calculation above during the period of batch 2007 through 8 semesters. The results obtained by DPMO process of 247159.09 to be used as a measure of the ability of the process to increase further.

Here is a chart of the results calculation of sigma level in Figure 4.6:

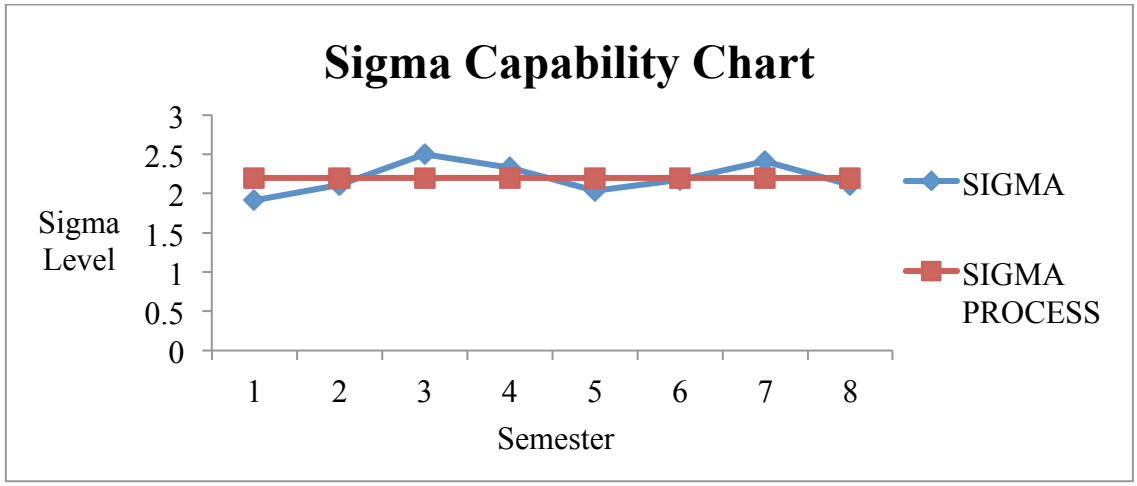


Figure 4.19 Sigma Capability Level Chart

From Figure 4.6 above, it can be seen that the chart pattern sigma capability levels of students defect shows varying results, due to the pattern of ups and downs of the

value of the calculation above during the period of batch 2007 through 8 semesters. The results obtained by Sigma process of 2.19541455 to be used as a baseline measure of performance for further improvements.

Table 4.11 p Control Charts Graph – Batch 2008

Semester	Batch	Inspected Students	Students Defect	Defects Percentages	LCL	CL	UCL
1	2008	13	7	0.538461538	-0.012379593	0.394230769	0.800841132
2		13	8	0.615384615	-0.012379593	0.394230769	0.800841132
3		13	2	0.153846154	-0.012379593	0.394230769	0.800841132
4		13	3	0.230769231	-0.012379593	0.394230769	0.800841132
5		13	2	0.153846154	-0.012379593	0.394230769	0.800841132
6		13	7	0.538461538	-0.012379593	0.394230769	0.800841132
7		13	1	0.076923077	-0.012379593	0.394230769	0.800841132
8		13	11	0.846153846	-0.012379593	0.394230769	0.800841132
Total		104	41	3.153846154			
Mean		13	5.125	0.394230769			
NP Bar		5.125					

From the calculation of the upper control limit, mean, and lower control limits on Table 4.10 above, it may be graphed p Control Charts to determine whether the data is statistically under control or not, is as follows:

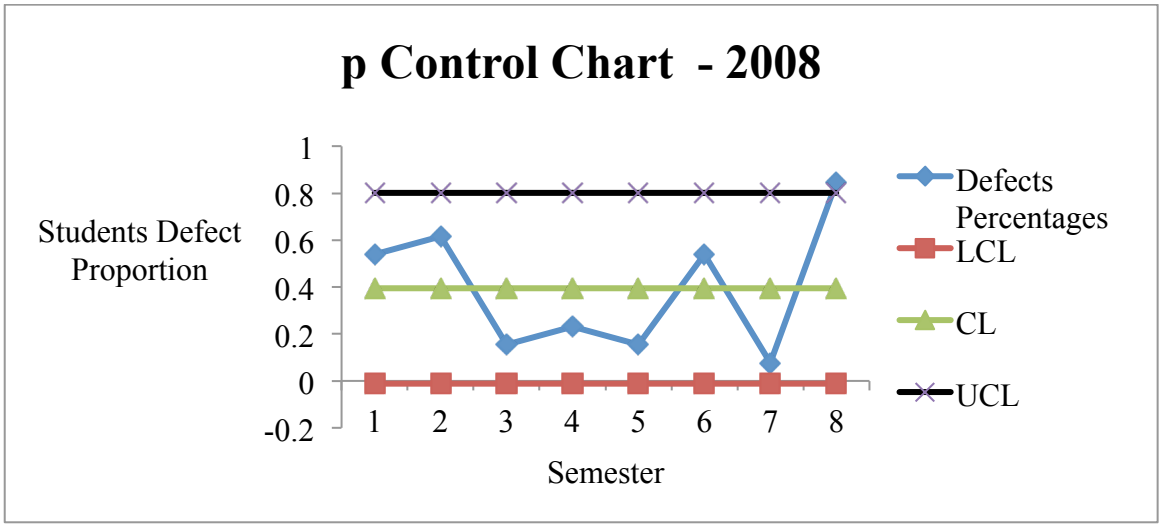


Figure 4.20 p Control Chart – Batch 2008

It can be seen from Figure 4.7 above, p control chart in batch 2008 shows the proportion of defects not in statistical control. There is 1 out-of-control point in the

chart shown, indicating that special causes are present. However, a closer look will show that there's something odd about the chart. Note that the lower control limit (LCL) is -0.012379593. Since the researcher is talking about defect, it is impossible to obtain any result that is less than zero. A process owner might argue that if the LCL is in the wrong place, then the upper control limit (UCL) may be as well. Alternatively, a special cause maybe caused by high levels of lateness graduation in this batch.

To continue the calculation level of DPMO and capability, it needed a state of statistical control must be achieved (Pyzdek, 2003). Therefore, the researcher tries to eliminate that special cause and normalized the LCL to be 0. Table 4.11 below shows the value after elimination and normalized UCL.

Table 4.12 p Control Charts Graph – Batch 2008 (elimination special cause & normalized control limit)

Semester	Batch	Inspected Students	Students Defect	Defects Percentages	LCL	CL	UCL
1		13	7	0.538461538	0	0.32967033	0.72081168
2		13	8	0.615384615	0	0.32967033	0.72081168
3		13	2	0.153846154	0	0.32967033	0.72081168
4	2008	13	3	0.230769231	0	0.32967033	0.72081168
5		13	2	0.153846154	0	0.32967033	0.72081168
6		13	7	0.538461538	0	0.32967033	0.72081168
7		13	1	0.076923077	0	0.32967033	0.72081168
Total		91	30	2.307692308			
Mean		13	4.2857143	0.32967033			
NP Bar		4.2857143					

From the calculation after elimination special cause and normalized of the upper control limit, mean, and lower control limits on Table 4.11 above, it may be graphed p Control Charts to determine whether the data is statistically under control or not, is as follows:

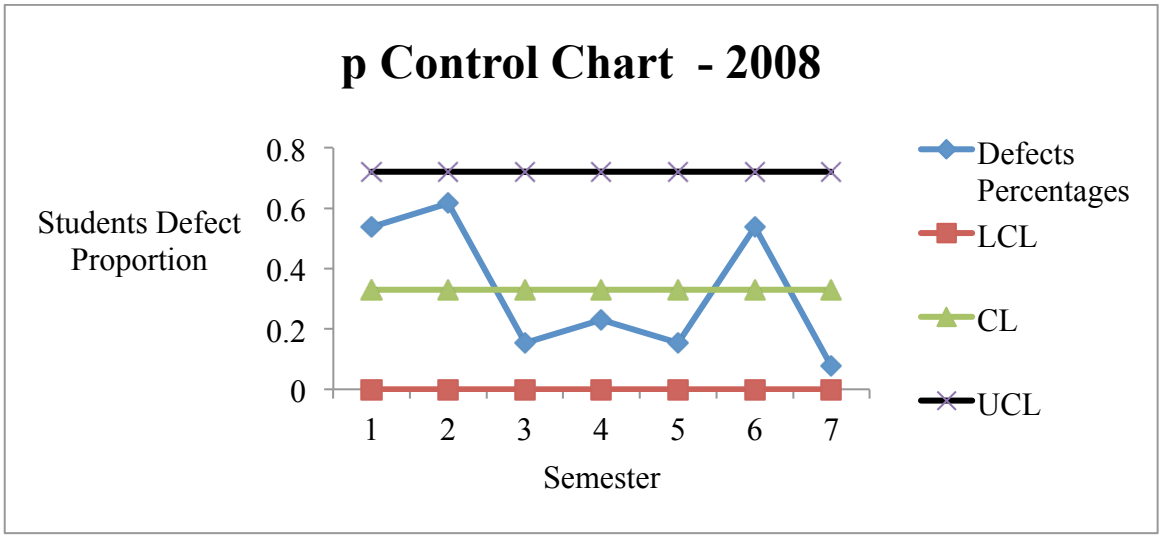


Figure 4.21 p Control Chart – Batch 2008 (elimination special cause and normalized control limit)

It can be seen from Figure 4.8 above, p control chart in batch 2008 after elimination special cause and normalized control limit shows the proportion of defects in statistical control. After calculating the p control chart and the result in statistical control, then the next calculation is DPMO level and sigma capability to know how big the quality of the International Program Industrial Engineering Program UII graduates. The following Table 4.12 is a calculation of DPMO and capability sigma:

Table 4.13 Calculation of DPMO & Sigma Level – Batch 2008

Semester	Batch	Inspected Students	Students Defect	Defects Percentages	DPO	DPMO	SIGMA
1		13	7	0.538461538	0.269230769	269230.7692	2.115141105
2		13	8	0.615384615	0.307692308	307692.3077	2.002402223
3		13	2	0.153846154	0.076923077	76923.07692	2.926076872
4	2008	13	3	0.230769231	0.115384615	115384.6154	2.698379702
5		13	2	0.153846154	0.076923077	76923.07692	2.926076872
6		13	7	0.538461538	0.269230769	269230.7692	2.115141105
7		13	1	0.076923077	0.038461538	38461.53846	3.268825039
Process		13	4.2857143	0.32967033	0.164835165	164835.1648	2.578863274

Here is a chart of the results calculation of DPMO and Sigma Level:

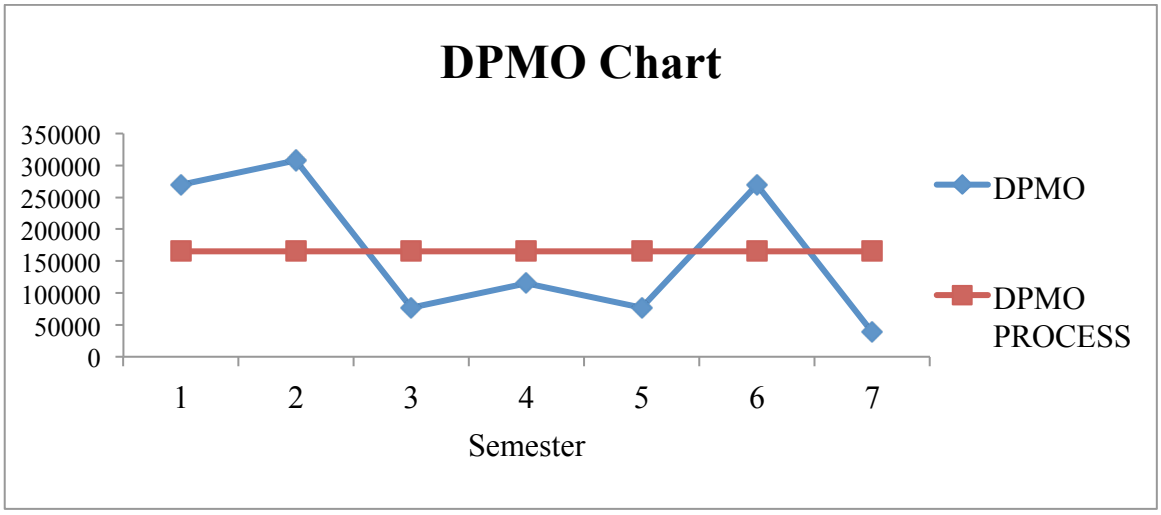


Figure 4.22 DPMO Level Chart

It can be seen from Figure 4.9 above, that the chart patterns of DPMO student defect shows varying results, due to the pattern of ups and downs of the value of the calculation above during the period of batch 2008 through 7 semesters. The results obtained by DPMO process of 164835.1648 to be used as a measure of the ability of the process to increase further.

Here is a chart of the results calculation of sigma level in Figure 4.10:

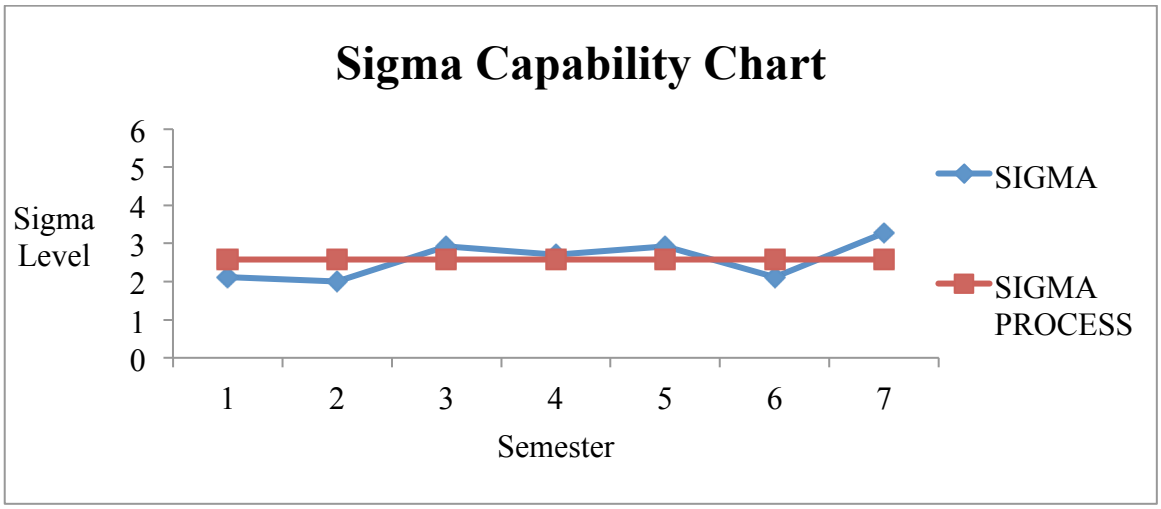


Figure 4.23 Sigma Capability Level Chart

From Figure 4.10 above, it can be seen that the chart pattern sigma capability levels of student defect shows varying results, due to the pattern of ups and downs of the value of the calculation above during the period of batch 2008 through 7 semesters. The

results obtained by Sigma process of 2.578863274 to be used as a baseline measure of performance for further improvements.

Table 4.14 p Control Charts Graph – Batch 2009

Semester	Batch	Inspected Students	Students Defect	Defects Percentages	LCL	CL	UCL
1	2009	20	7	0.35	0.214707065	0.561938854	0.909170644
2		19	11	0.578947368	0.214707065	0.561938854	0.909170644
3		19	12	0.631578947	0.214707065	0.561938854	0.909170644
4		19	12	0.631578947	0.214707065	0.561938854	0.909170644
5		19	8	0.421052632	0.214707065	0.561938854	0.909170644
6		17	10	0.588235294	0.214707065	0.561938854	0.909170644
7		17	7	0.411764706	0.214707065	0.561938854	0.909170644
8		17	15	0.882352941	0.214707065	0.561938854	0.909170644
Total		147	82	4.495510836			
Mean		18.375	10.25	0.561938854			
NP Bar		10.325627					

From the calculation of the upper control limit, mean, and lower control limits on Table 4.13 above, it may be graphed p Control Charts to determine whether the data is statistically under control or not, is as follows:

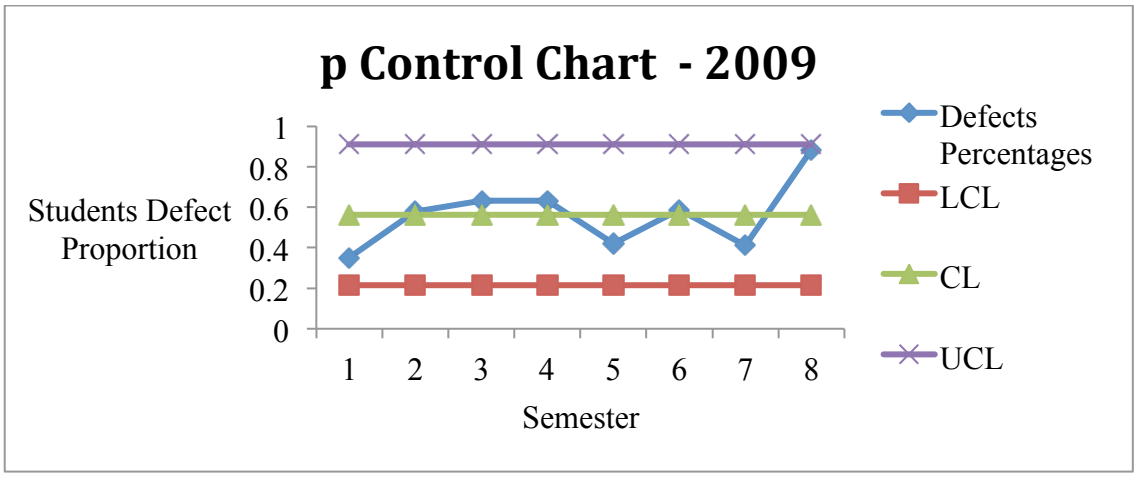


Figure 4.24 p Control Chart – Batch 2009

It can be seen from Figure 4.11 above, p control chart in batch 2009 shows the proportion of defects in statistical control. After calculating the p control chart and the result in statistical control, then the next calculation is DPMO level and sigma capability to know how big the quality of the International Program Industrial

Engineering Program UII graduates. The following Table 4.14 is a calculation of DPMO and capability sigma:

Table 4.15 Calculation of DPMO & Sigma Level – Batch 2009

Semester	Batch	Inspected Students	Students Defect	Defects Percentages	DPO	DPMO	SIGMA
1	2009	20	7	0.35	0.175	175000	2.434589291
2		19	11	0.578947368	0.289473684	289473.6842	2.054922943
3		19	12	0.631578947	0.315789474	315789.4737	1.979505653
4		19	12	0.631578947	0.315789474	315789.4737	1.979505653
5		19	8	0.421052632	0.210526316	210526.3158	2.30459638
6		17	10	0.588235294	0.294117647	294117.6471	2.041395085
7		17	7	0.411764706	0.205882353	205882.3529	2.320792088
8		17	15	0.882352941	0.294117647	294117.6471	2.041395085
Process		18.375	10.25	0.561938854	0.262587074	262587.0743	2.144587772

Here is a chart of the results calculation of DPMO and Sigma Level:

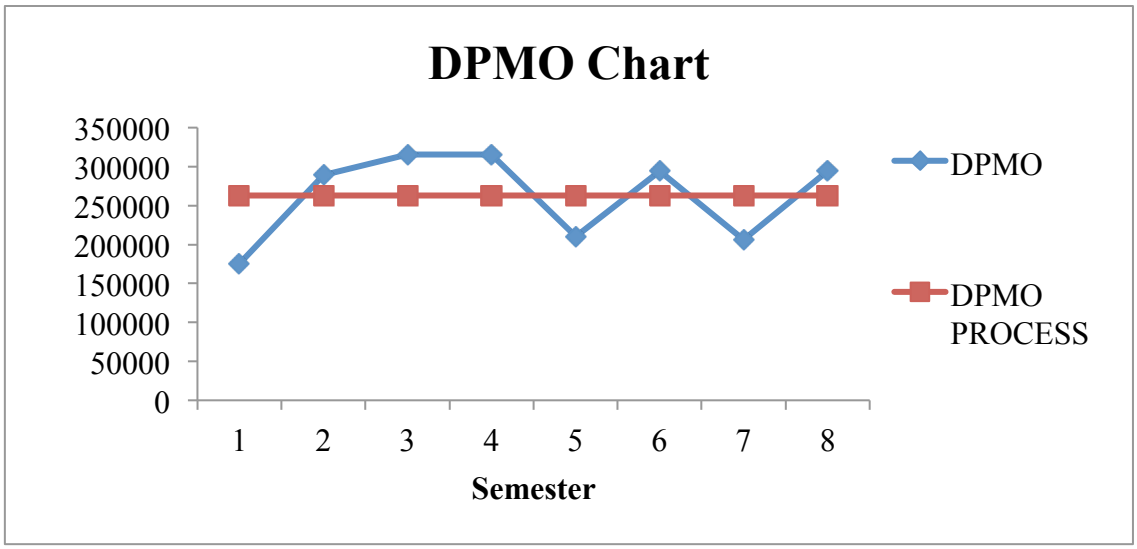


Figure 4.25 DPMO Level Chart

It can be seen from Figure 4.12 above, that the chart patterns of DPMO student defect shows varying results, due to the pattern of ups and downs of the value of the calculation above during the period of batch 2009 through 8 semesters. The results obtained by DPMO process of 262587.0743 to be used as a measure of the ability of the process to increase further.

Here is a chart of the results calculation of sigma level in Figure 4.13:

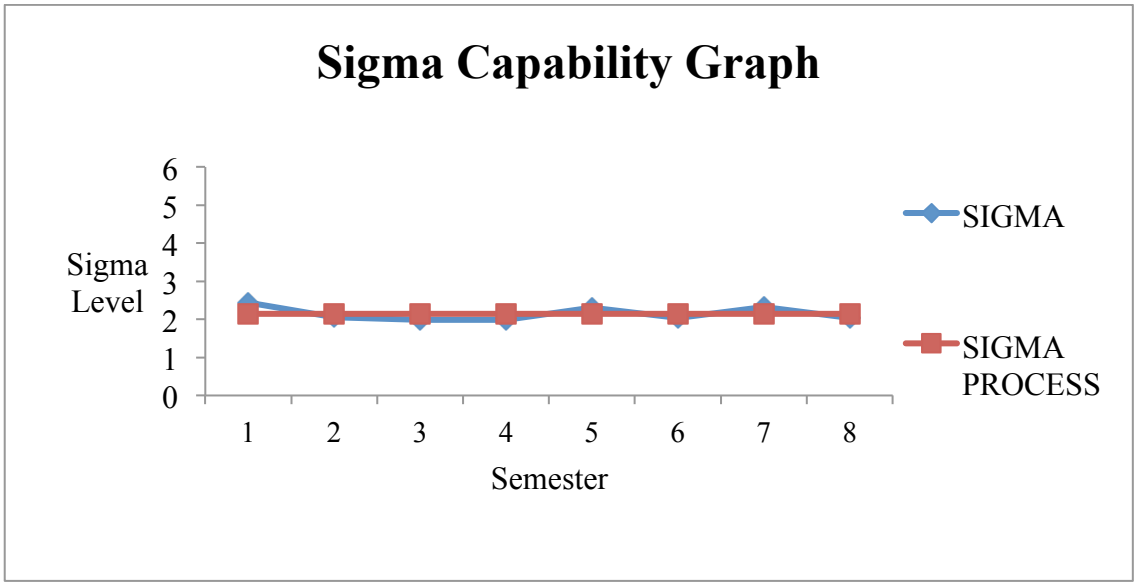


Figure 4.26 Sigma Capability Level Chart

From Figure 4.12 above, it can be seen that the chart pattern sigma capability levels of student defect findings shows unvarying results, because of a little bit up and down pattern of the value of the calculation above during the period of batch 2009 through 8 semesters. . The results obtained by Sigma process of 2.144587772 to be used as a baseline measure of performance for further improvements.

Table 4.16 p Control Charts Graph – Batch 2010

Semester	Batch	Inspected Students	Students Defect	Defects Percentages	LCL	CL	UCL
1	2010	15	2	0.133333333	0.030534433	0.429166667	0.8277989
2		15	7	0.466666667	0.030534433	0.429166667	0.8277989
3		15	5	0.333333333	0.030534433	0.429166667	0.8277989
4		14	7	0.5	0.030534433	0.429166667	0.8277989
5		13	2	0.153846154	0.030534433	0.429166667	0.8277989
6		13	4	0.307692308	0.030534433	0.429166667	0.8277989
7		13	8	0.615384615	0.030534433	0.429166667	0.8277989
8		13	12	0.923076923	0.030534433	0.429166667	0.8277989
Total		111	47	3.433333333			
Mean		14	5.875	0.429166667			
NP Bar		5.9546875					

From the calculation of the upper control limit, mean, and lower control limits on Table 4.15 above, it may be graphed p Control Charts to determine whether the data is statistically under control or not, is as follows:

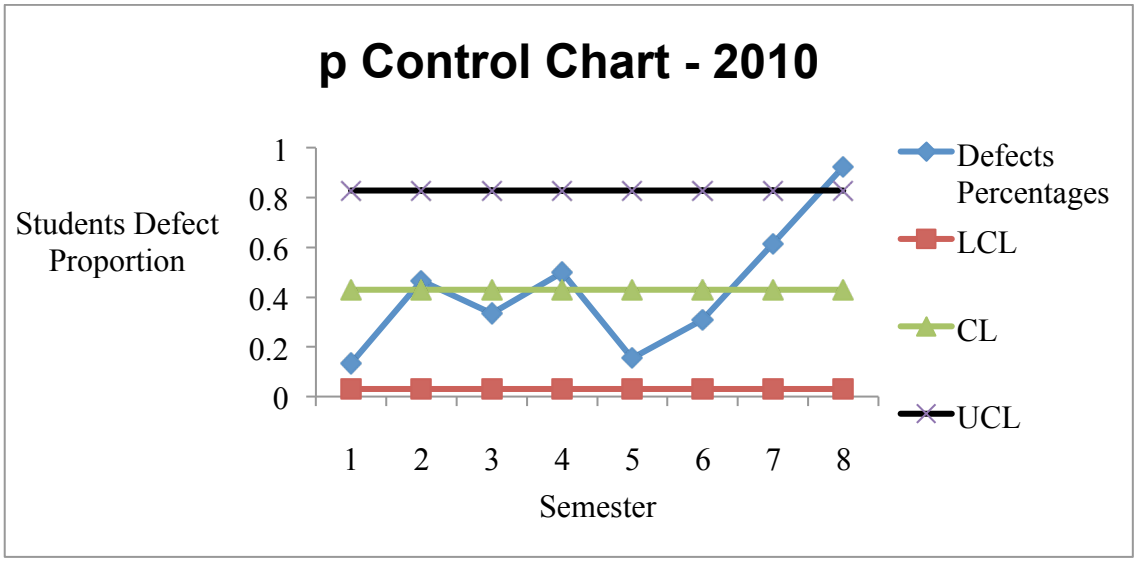


Figure 4.27 p Control Chart – Batch 2010

It can be seen from Figure 4.14 above, p control chart in batch 2010 shows the proportion of defects not in statistical control. There is 1 out-of-control point in the chart shown, indicating that special causes are present. A special cause maybe caused by high levels of lateness graduation in this batch.

To continue the calculation level of DPMO and capability, it needed a state of statistical control must be achieved (Pyzdek, 2003). Therefore, the researcher tries to eliminate that special cause. Table 4.16 below shows the value after elimination special cause.

Table 4.17 p Control Charts Graph – Batch 2010 (eliminating special cause)

Semester	Batch	Inspected Students	Students Defect	Defects Percentages	LCL	CL	UCL
1		15	2	0.133333333	-0.025920862	0.358608059	0.743136979
2		15	7	0.466666667	-0.025920862	0.358608059	0.743136979
3		15	5	0.333333333	-0.025920862	0.358608059	0.743136979
4	2010	14	7	0.5	-0.025920862	0.358608059	0.743136979
5		13	2	0.153846154	-0.025920862	0.358608059	0.743136979
6		13	4	0.307692308	-0.025920862	0.358608059	0.743136979
7		13	8	0.615384615	-0.025920862	0.358608059	0.743136979
Total		98	35	2.51025641			
Mean		14	5	0.358608059			
NP Bar		5.0205128					

From the calculation after elimination special cause on Table 4.17 above, it may be graphed p Control Charts to determine whether the data is statistically under control or not, is as follows:

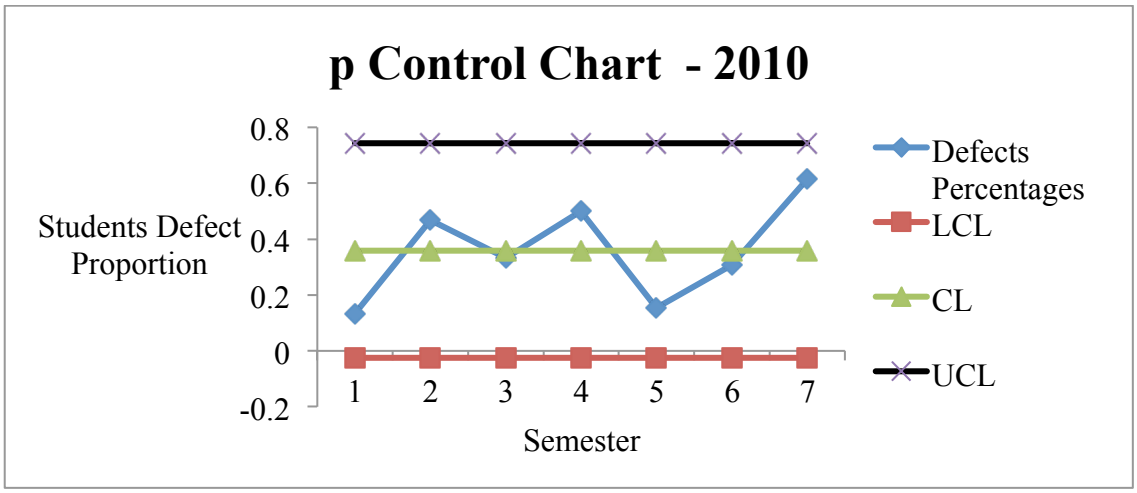


Figure 4.28 p Control Chart – Batch 2010 (elimination special cause)

It can be seen from Figure 4.15 above, p control chart in batch 2010 after elimination special cause shows the proportion of defects in statistical control. After calculating the p control chart and the result in statistical control, then the next calculation is DPMO level and sigma capability to know how big the quality of the International Program Industrial Engineering Program UII graduates. The following Table 4.17 is a calculation of DPMO and capability sigma:

Table 4.18 Calculation of DPMO & Sigma Level – Batch 2010

Semester	Batch	Inspected Students	Students Defect	Defects Percentages	DPO	DPMO	SIGMA
1		15	2	0.538461538	0.066666667	66666.66667	3.001085946
2		15	7	0.615384615	0.233333333	233333.3333	2.227913291
3		15	5	0.153846154	0.166666667	166666.6667	2.467421566
4	2010	14	7	0.230769231	0.25	250000	2.17448975
5		13	2	0.153846154	0.076923077	76923.07692	2.926076872
6		13	4	0.538461538	0.153846154	153846.1538	2.520076233
7		13	8	0.076923077	0.307692308	307692.3077	2.002402223
Process		14	5	0.358608059	0.179304029	179304.0293	2.474209412

Here is a chart of the results calculation of DPMO and Sigma Level:

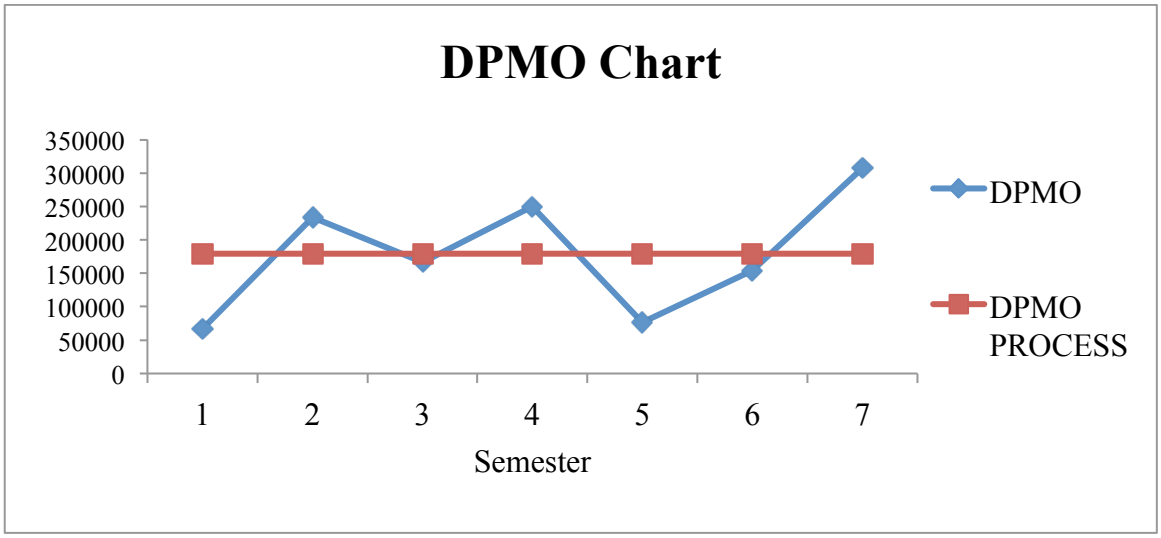


Figure 4.29 DPMO Level Chart

It can be seen from Figure 4.16 above, that the chart patterns of DPMO student defect shows varying results, due to the pattern of ups and downs of the value of the calculation above during the period of batch 2010 through 7 semesters. The results obtained by DPMO process of 179304.0293 to be used as a measure of the ability of the process to increase further.

Here is a chart of the results calculation of sigma level in Figure 4.17:

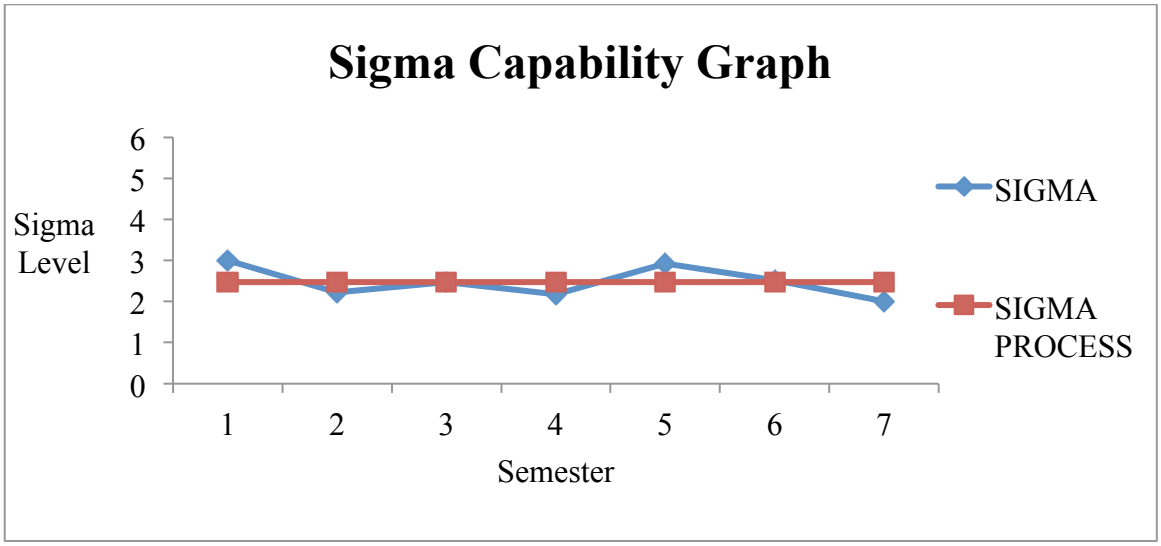


Figure 4.30 Sigma Capability Level Chart

From Figure 4.17 above, it can be seen that the chart pattern sigma capability levels of students defect shows varying results, due to the pattern of ups and downs of the value of the calculation above during the period of batch 2010 through 7 semesters. The results obtained by Sigma process of 2.474209412 to be used as a baseline measure of performance for further improvements.

Table 4.19 p Control Charts Graph – Batch 2011

Semester	Batch	Inspected Students	Students Defect	Defects Percentages	LCL	CL	UCL
1	2011	23	14	0.608695652	0.129231651	0.443428854	0.757626056
2		23	12	0.52173913	0.129231651	0.443428854	0.757626056
3		23	12	0.52173913	0.129231651	0.443428854	0.757626056
4		23	7	0.304347826	0.129231651	0.443428854	0.757626056
5		22	10	0.454545455	0.129231651	0.443428854	0.757626056
6		22	4	0.181818182	0.129231651	0.443428854	0.757626056
7		22	3	0.136363636	0.129231651	0.443428854	0.757626056
8		22	18	0.818181818	0.129231651	0.443428854	0.757626056
Total		180	83	3.683794466			
Mean		23	10.375	0.460474308			
NP Bar		10.360672					

From the calculation of the upper control limit, mean, and lower control limits on Table 4.18 above, it may be graphed p Control Charts to determine whether the data is statistically under control or not, is as follows:

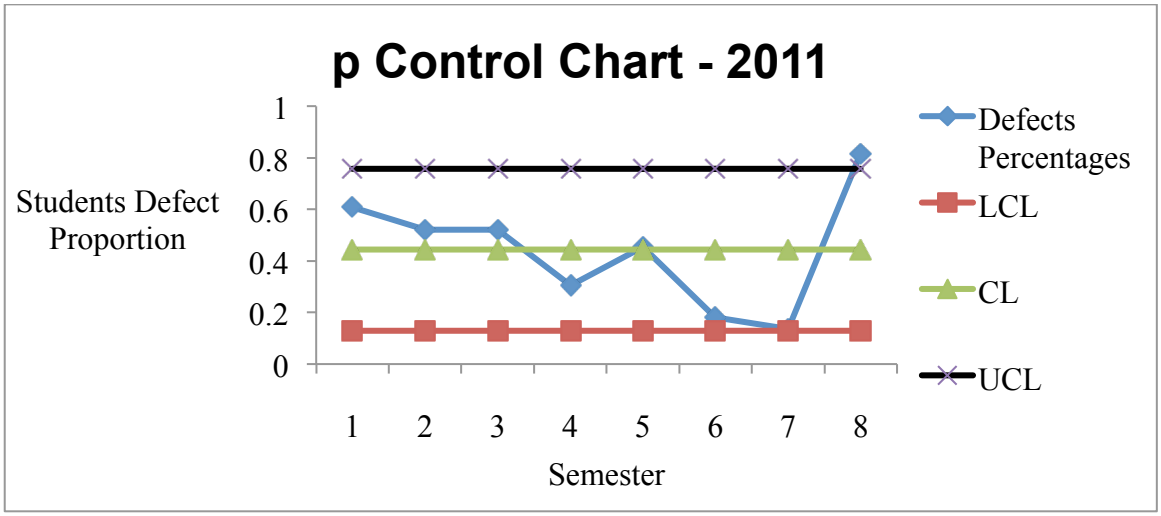


Figure 4.31 p Control Chart – Batch 2011

It can be seen from Figure 4.18 above, p control chart in batch 2011 shows the proportion of defects not in statistical control. There is 1 out-of-control point in the chart shown, indicating that special causes are present. A special cause maybe caused by high levels of lateness graduation in this batch.

To continue the calculation level of DPMO and capability, it needed a state of statistical control must be achieved (Pyzdek, 2003). Therefore, the researcher tries to eliminate that special cause. Table 4.19 below shows the value after elimination special cause.

Table 4.20 p Control Charts Graph – Batch 2011 (eliminating special cause)

Semester	Batch	Inspected Students	Students Defect	Defects Percentages	LCL	CL	UCL
1		23	14	0.608695652	0.081916345	0.389892716	0.697869087
2		23	12	0.52173913	0.081916345	0.389892716	0.697869087
3		23	12	0.52173913	0.081916345	0.389892716	0.697869087
4	2011	23	7	0.304347826	0.081916345	0.389892716	0.697869087
5		22	10	0.454545455	0.081916345	0.389892716	0.697869087
6		22	4	0.181818182	0.081916345	0.389892716	0.697869087
7		22	3	0.136363636	0.081916345	0.389892716	0.697869087
Total		158	62	2.729249012			
Mean		23	8.8571429	0.389892716			
NP Bar		8.8004356					

From the calculation after elimination special cause on Table 4.19 above, it may be graphed p Control Charts to determine whether the data is statistically under control or not, is as follows:

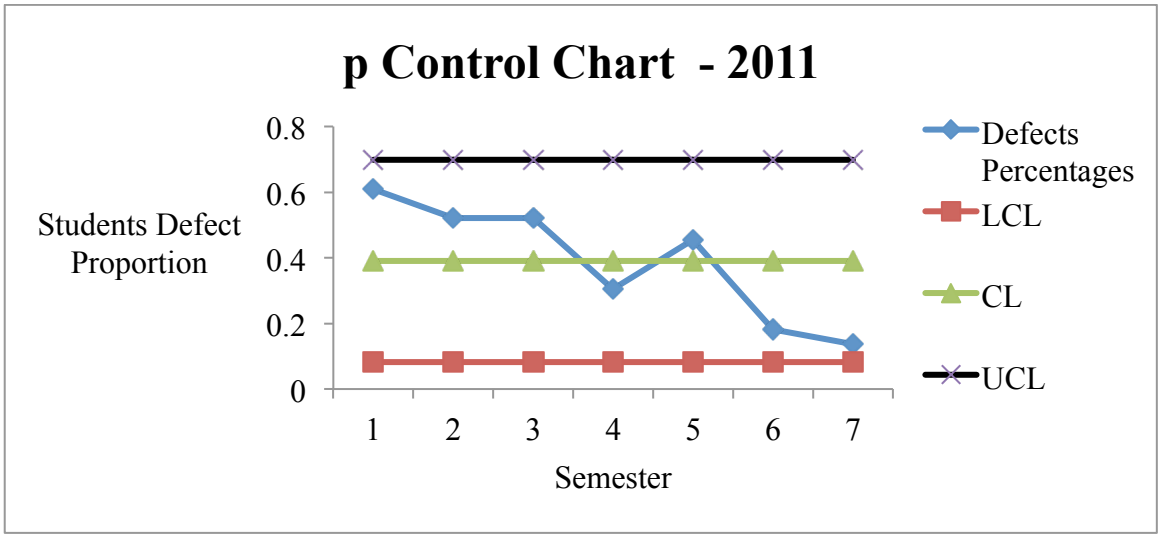


Figure 4.32 p Control Chart – Batch 2011 (after elimination special cause)

It can be seen from Figure 4.19 above, p control chart in batch 2011 after elimination special cause shows the proportion of defects in statistical control. After calculating the p control chart and the result in statistical control, then the next calculation is DPMO level and sigma capability to know how big the quality of the International Program Industrial Engineering Program UII graduates. The following Table 4.20 is a calculation of DPMO and capability sigma:

Table 4.21 Calculation of DPMO & Sigma Level – Batch 2011

Semester	Batch	Inspected Students	Students Defect	Defects Percentages	DPO	DPMO	SIGMA
1		23	14	0.608695652	0.304347826	304347.8261	2.011936214
2		23	12	0.52173913	0.260869565	260869.5652	2.14066689
3		23	12	0.52173913	0.260869565	260869.5652	2.14066689
4	2011	23	7	0.304347826	0.152173913	152173.913	2.527154273
5		22	10	0.454545455	0.227272727	227272.7273	2.247858595
6		22	4	0.181818182	0.090909091	90909.09091	2.835177736
7		22	3	0.136363636	0.068181818	68181.81818	2.989470042
Process		23	8.8571429	0.389892716	0.194946358	194946.358	2.413275806

Here is a chart of the results calculation of DPMO and Sigma Level:

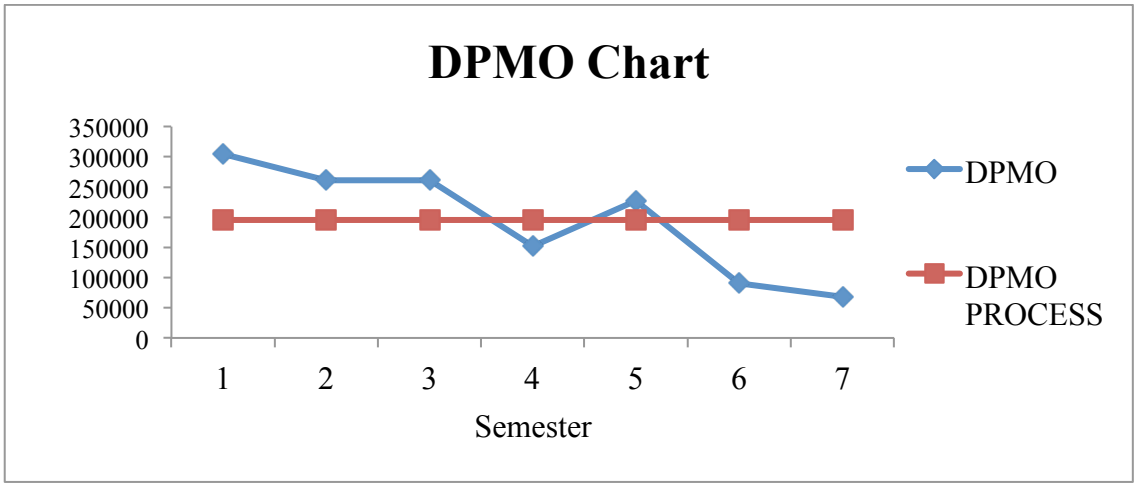


Figure 4.33 DPMO Level Chart

It can be seen from Figure 4.20 above, that the chart patterns of DPMO student defect shows varying results, due to the pattern of ups and downs of the value of the calculation above during the period of batch 2011 through 7 semesters. The results obtained by DPMO process of 194946.358 to be used as a measure of the ability of the process to increase further.

Here is a chart of the results calculation of sigma level in Figure 4.21

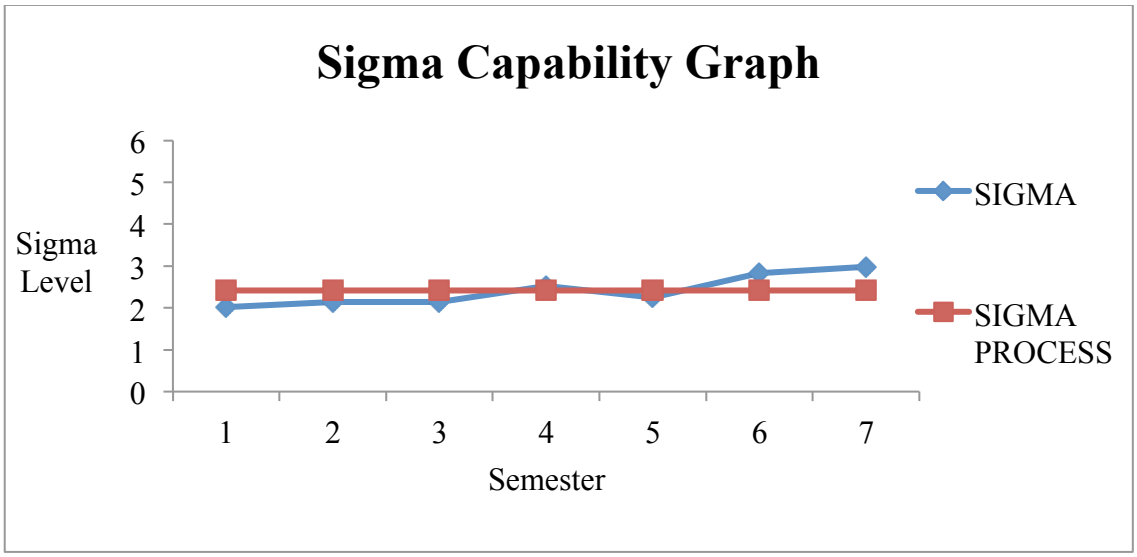


Figure 4.34 Sigma Capability Level Chart

From Figure 4.21 above, it can be seen that the chart pattern sigma capability levels of student defect shows varying results, due to the pattern of ups and downs of the value

of the calculation above during the period of batch 2011 through 7 semesters. The results obtained by Sigma process of 2.413275806 to be used as a baseline measure of performance for further improvements.

Table 4.22 p Control Charts Graph – Batch 2012

Semester	Batch	Inspected Students	Students Defect	Defects Percentages	LCL	CL	UCL
1	2012	20	14	0.7	0.177446203	0.519078947	0.860711692
2		20	8	0.4	0.177446203	0.519078947	0.860711692
3		19	7	0.368421053	0.177446203	0.519078947	0.860711692
4		19	12	0.631578947	0.177446203	0.519078947	0.860711692
5		19	10	0.526315789	0.177446203	0.519078947	0.860711692
6		19	8	0.421052632	0.177446203	0.519078947	0.860711692
7		19	4	0.210526316	0.177446203	0.519078947	0.860711692
8		19	17	0.894736842	0.177446203	0.519078947	0.860711692
Total		154	80	4.152631579			
Mean		19	10	0.519078947			
NP Bar		9.9922697					

From the calculation of the upper control limit, mean, and lower control limits on Table 4.21 above, it may be graphed p Control Charts to determine whether the data is statistically under control or not, is as follows:

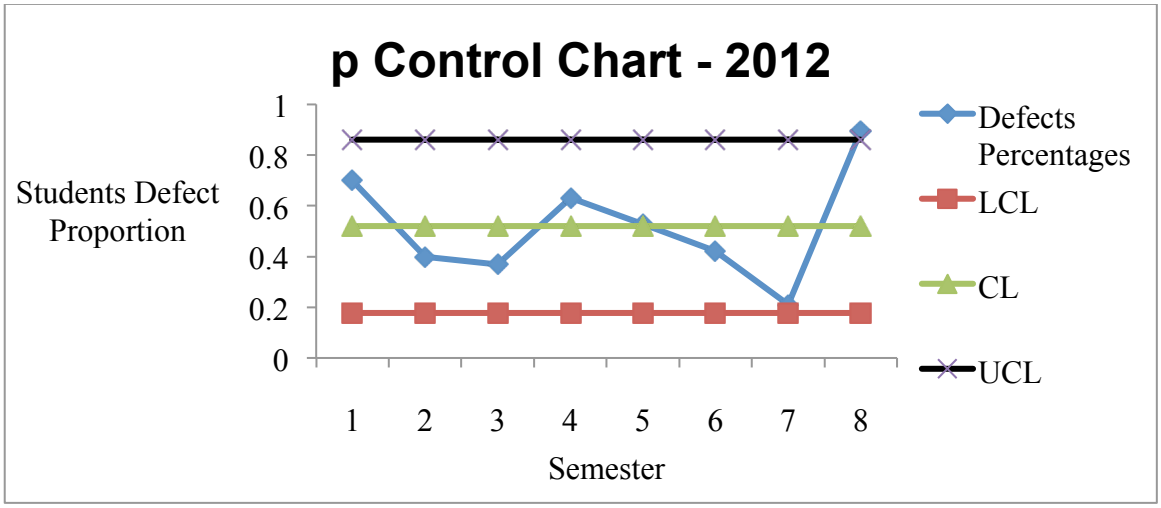


Figure 4.35 p Control Chart – Batch 2011

It can be seen from Figure 4.22 above, p control chart in batch 2011 showed the proportion of defects not in statistical control. There is 1 out-of-control point in the chart shown, indicating that special causes are present. A special cause maybe caused by high levels of lateness graduation in this batch.

To continue the calculation level of DPMO and capability, it needed a state of statistical control must be achieved (Pyzdek, 2003). Therefore, the researcher tries to eliminate that special cause. Table 4.22 below shows the value after elimination special cause.

Table 4.23 p Control Charts Graph – Batch 2012 (eliminating special cause)

Semester	Batch	Inspected Students	Students Defect	Defects Percentages	LCL	CL	UCL
1		20	14	0.7	0.124666664	0.465413534	0.806160403
2		20	8	0.4	0.124666664	0.465413534	0.806160403
3		19	7	0.368421053	0.124666664	0.465413534	0.806160403
4	2012	19	12	0.631578947	0.124666664	0.465413534	0.806160403
5		19	10	0.526315789	0.124666664	0.465413534	0.806160403
6		19	8	0.421052632	0.124666664	0.465413534	0.806160403
7		19	4	0.210526316	0.124666664	0.465413534	0.806160403
Total		135	63	3.257894737			
Mean		19	9	0.465413534			
NP Bar		8.9758324					

From the calculation after elimination special cause on Table 4.22 above, it may be graphed p Control Charts to determine whether the data is statistically under control or not, is as follows:

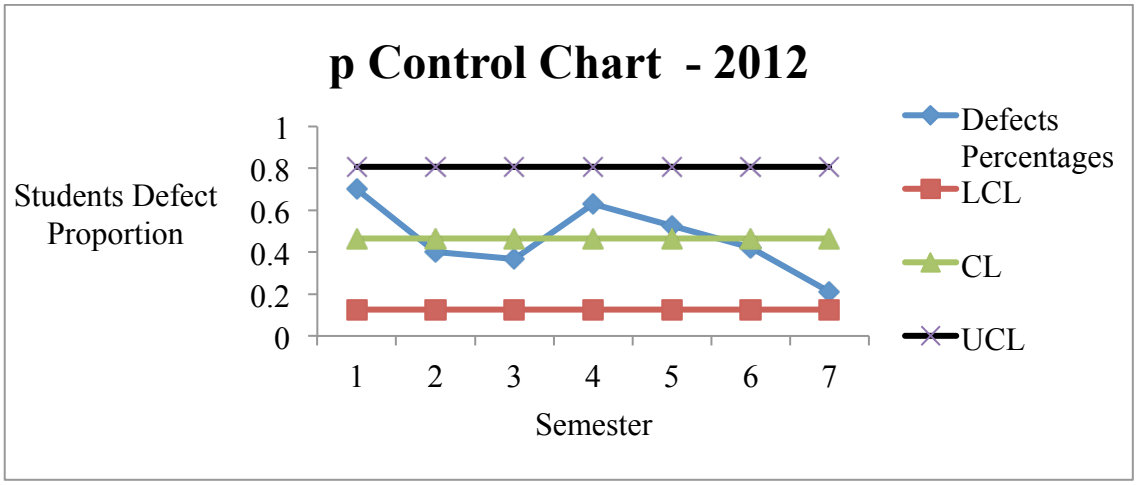


Figure 4.36 p Control Chart – Batch 2012 (elimination special cause)

It can be seen from Figure 4.23 above, p control chart in batch 2012 after elimination special cause shows the proportion of defects in statistical control. After calculating the p control chart and the result in statistical control, then the next calculation is DPMO level and sigma capability to know how big the quality of the International Program Industrial Engineering Program UII graduates. The following Table 4.23 is a calculation of DPMO and capability sigma:

Table 4.24 Calculation of DPMO & Sigma Level – Batch 2012

Semester	Batch	Inspected Students	Students Defect	Defects Percentages	DPO	DPMO	SIGMA
1		20	14	0.7	0.35	350000	1.885320466
2		20	8	0.4	0.2	200000	2.341621234
3		19	7	0.368421053	0.184210526	184210.5263	2.399434908
4	2012	19	12	0.631578947	0.315789474	315789.4737	1.979505653
5		19	10	0.526315789	0.263157895	263157.8947	2.133640001
6		19	8	0.421052632	0.210526316	210526.3158	2.30459638
7		19	4	0.210526316	0.105263158	105263.1579	2.75211952
Process		23	8.8571429	0.389892716	0.232706767	232706.7669	2.256605452

Here is a chart of the results calculation of DPMO and Sigma Level:

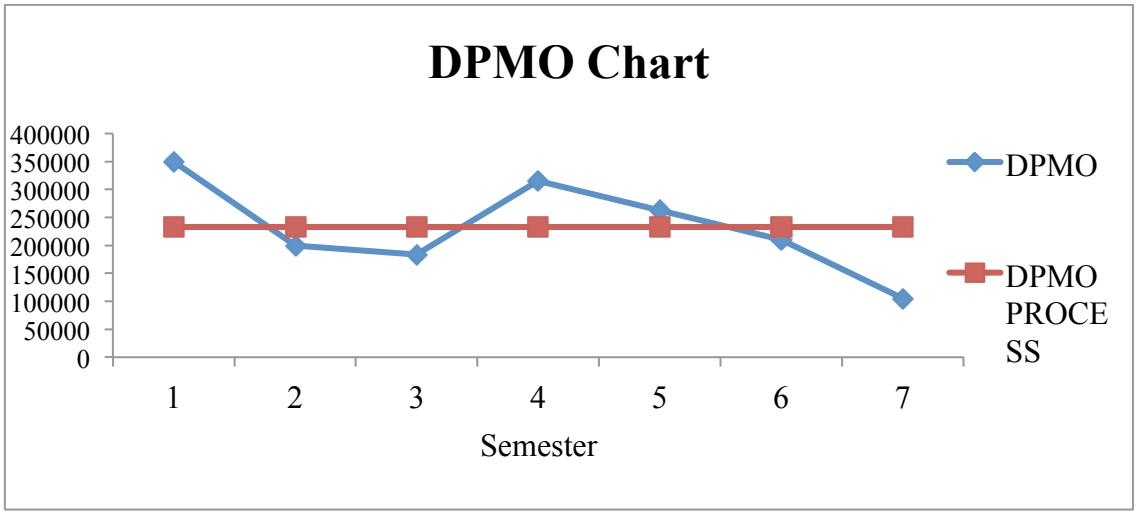


Figure 4.37 DPMO Level Chart

It can be seen from Figure 4.24 above, that the chart patterns of DPMO student defect shows varying results, due to the pattern of ups and downs of the value of the calculation above during the period of batch 2012 through 7 semesters. The results obtained by DPMO process of 232706.7669 to be used as a measure of the ability of the process to increase further.

Here is a chart of the results calculation of sigma level in Figure 4.25

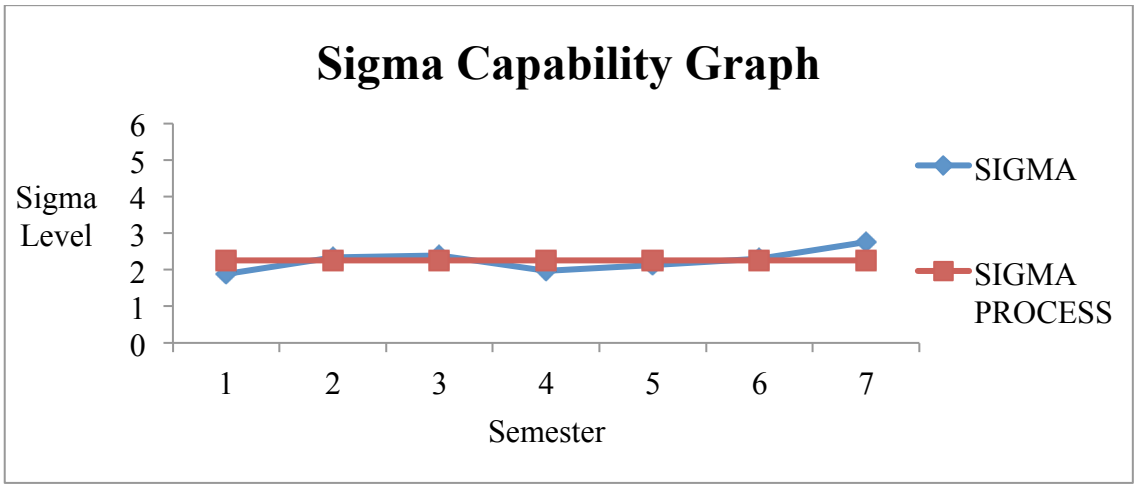


Figure 4.38 Sigma Capability Level Chart

From Figure 4.25 above, it can be seen that the chart pattern sigma capability levels of student defect shows varying results, due to the pattern of ups and downs of the value

of the calculation above during the period of batch 2012 through 7 semesters. The results obtained by Sigma process of 2.256605452 to be used as a baseline measure of performance for further improvements.

4.2.5 Analyze

Analyze phase is done based on conditions measured in the previous stage. This is performed to examine in depth causes of non-fulfillment of CTQ's requirement, covers establishing a baseline process, and knowledge discovery (Pyzdek, 2003), From the findings level Sigma capabilities calculation during the batch 2007 – 2012 in measure phase, so it can be obtained conclusion as follows:

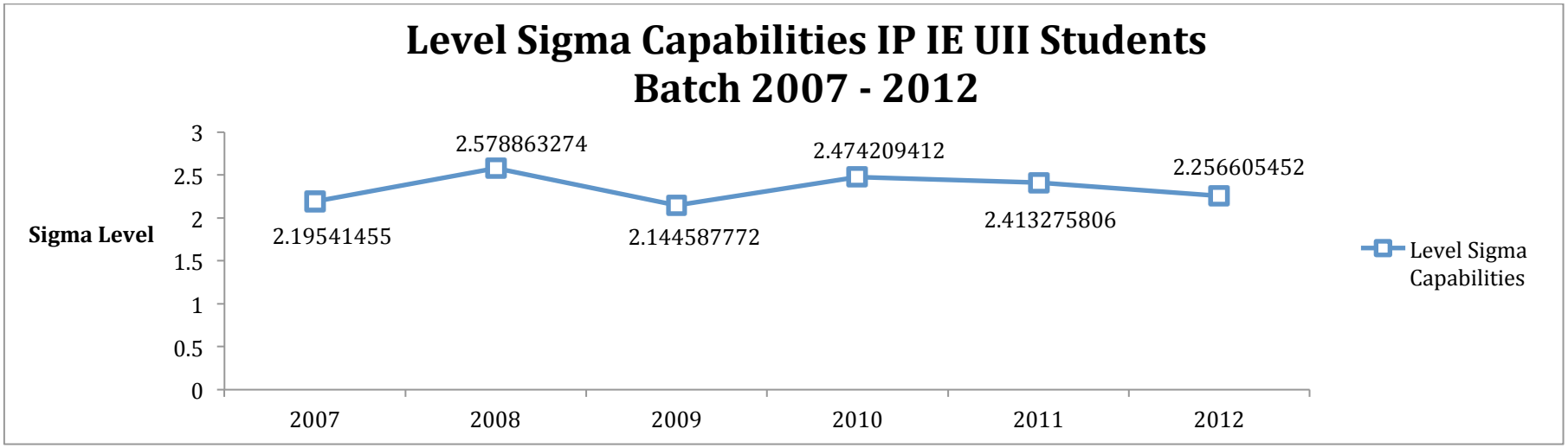


Figure 4.39 Level Sigma Capabilities Batch 2007 - 2012

From the Figure 4.26 above, it can be seen that the smallest level of capability Sigma during batch 2007 – 2012 that is in batch 2009

Another findings that researcher get from measure phase is process capability index of attribute data. To search process capability index from attribute data, its formula is:

$Cp = 1 - \bar{p}$

$Cp = Process\ Capability\ Index$

$\bar{p} = Defect\ Proportion\ Average$

(Pyzdek, 2003)

Here is the Process Capability Index defect student batch 2007 – 2012.

Table 4.25 Process Capability Index (Cp) defect student

Batch	Mean Proportion Defects	Process Capability indexes (Cp)
2007	0.528409091	0.471590909
2008	0.32967033	0.67032967
2009	0.561938854	0.438061146
2010	0.358608059	0.641391941
2011	0.389892716	0.610107284
2012	0.465413534	0.534586466

From the Table 4.24 above, the Process Capability Index (Cp) is illustrated in the following graph:

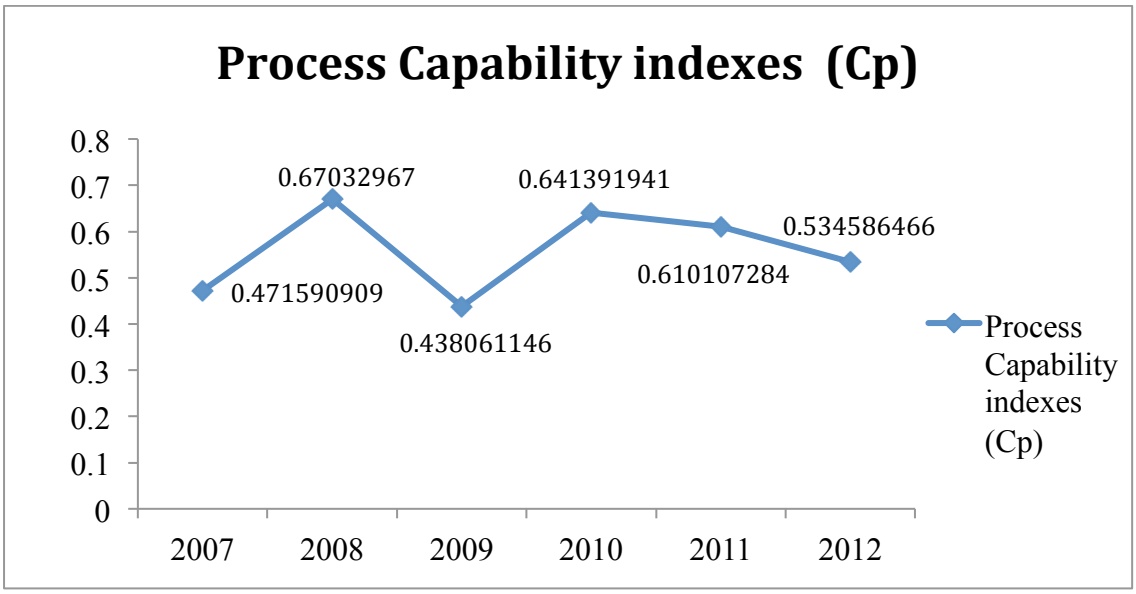


Figure 4.40 Process Capability Indexes Batch 2007 - 2012

From the Figure 4.39 above, the calculation results of Cp attribute data on the batch 2007 to 2012, it shows that the value of Cp is varying on every batch from 2007 until 2012. It means that, there is a chance or potential quality that Industrial Engineering graduates get considering how input, process, and output happened in this batch. Thus, if the management wants to improve process capability to produce graduates that fit based on process condition stable, common variations and common causes inherent in the process should be reduced, so that needs to be improved its performance by improving the process.

Before the management improve the Cp and Sigma capabilities IP IE UII student, it is needed to determine what kind of project should management does that give significance benefit. The project conducted based on the kind of CTQ's that want to improve to meet quality requirement. In this research, there are 3 CTQs that determined based on that possible to collect that are GPA below 3, Lateness Graduation, Student Attrition. Amount of 3 CTQs will show in the Table 4.25 below

Table 4.26 Amount of 3 CTQs in every Batch

Batch	Kind of Defects	Amount of Defects	Total
2007	GPA below 3	84	105
	Lateness Graduation	18	
	Student Attrition	3	
2008	GPA below 3	33	50
	Lateness Graduation	11	
	Student Attrition	6	
2009	GPA below 3	56	80
	Lateness Graduation	15	
	Student Attrition	9	
2010	GPA below 3	35	57
	Lateness Graduation	12	
	Student Attrition	10	
2011	GPA below 3	66	92
	Lateness Graduation	18	
	Student Attrition	8	
2012	GPA below 3	69	92
	Lateness Graduation	17	
	Student Attrition	6	

From the Table 4.26 above, it can be seen that the highest defect come from batch 2007 and the lowest come from 2008. It means that highest amount CTQs does not always show lowest Sigma capabilities and Cp.

After that, the management should decide 1 from 3 kind of defects that should be conducted as project that give significance improve. Therefore, management should determine critical percentage critical to qualify the potential of industrial engineering graduates, as follows:

Table 4.27 Cumulative Percentage CTQ Students Defect

IP IE Defects Student Percentage				
No	Kind of Defect	Amount of Defects	Defects Percentage	Cumulative Percentage
1	GPA below 3	343	73.29%	73.29%
2	Students Attrition	91	19.44%	92.74%
3	Lateness Graduation	34	7.26%	100.00%
	Total of Amount	468		

After calculating the percentage of the critical to quality of engineering graduates as shown in Table 4.27 above, then researcher have created the Pareto diagram to determine the significance student defect to make project identification and propose improvement in order to increase level sigma and capability process. Here is a Pareto diagram critical to quality graduates industrial engineering defects:

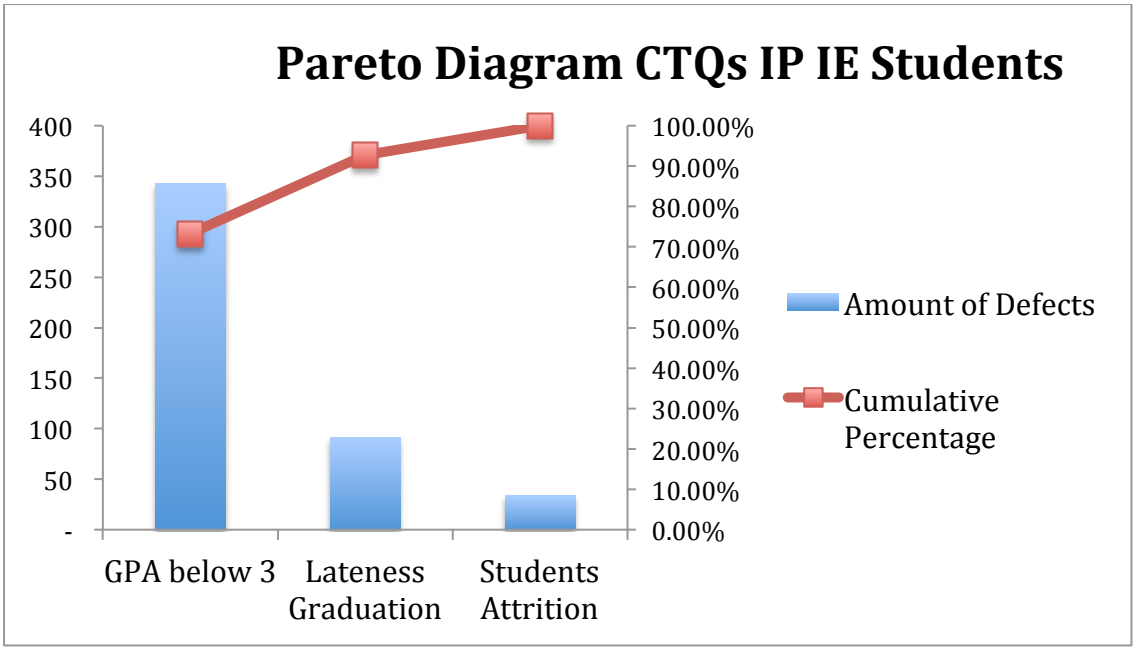


Figure 4.41 Pareto Diagram CTQs IP IE UII Students

From the figure 4.40 above, it can be seen that the dominant factor of defect in the 2007-2012 batch is GPA below 3 around 343 defects (73.29%), the second one is around 91 lateness graduation defects (19.44%) and the last is student attrition around 34 defects (7.26%).

Further analysis is conducted using Fishbone diagram. Fishbone diagram is used to find the root of the problem based on the determinants of quality that led to decreasing quality in Fishbone diagram. In this analysis, GPA below 3 is chosen to be analyzed in Fishbone Diagram due to the highest significance improvement based on the Pareto diagram that has been conducted. From this type of defect, it can occur due to several factors, such as Man, Method, Milieu, and Management. From these factors, it can be identified source and root cause of defects. These factors further illustrated in the fishbone diagram below.

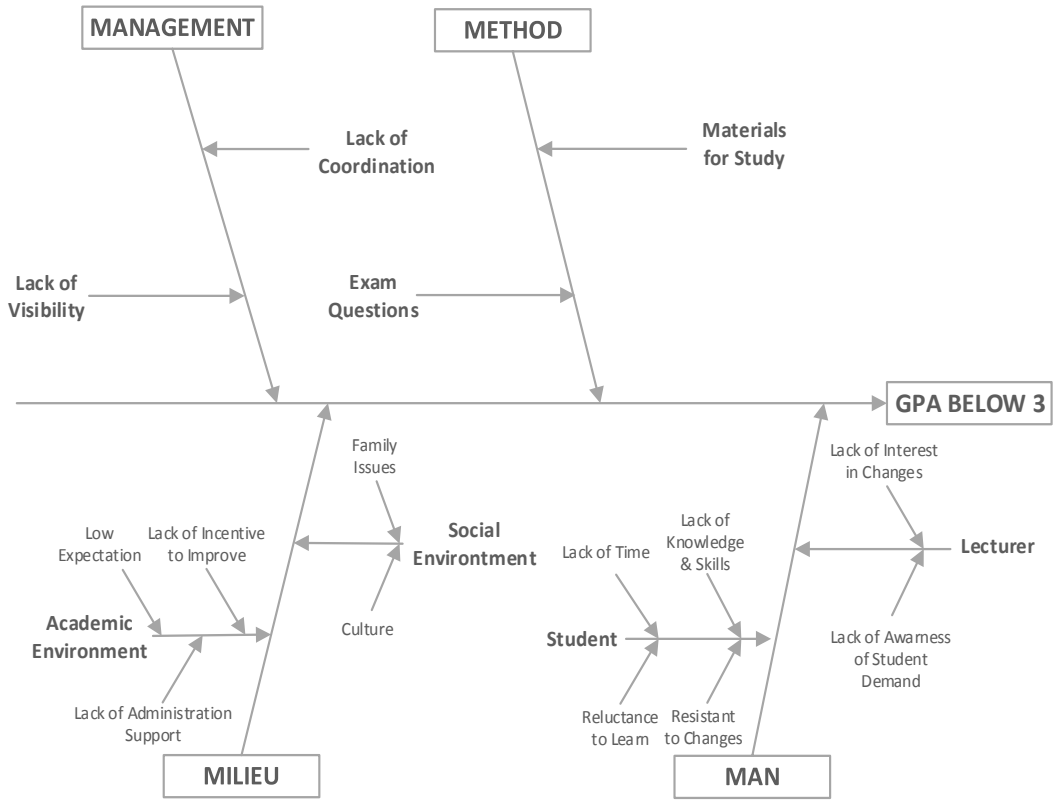


Figure 4.42 Fishbone Diagram Causes GPA Below 3

Based on the Figure 4.41 above, the factors that lead to GPA below 3 are:

1. Man

- Student: Problem of GPA below 3 sometimes causes by the student itself, student as a customer also can be co-worker in this process due to a load academic that has given to the student. Lack of time, lack of knowledge & skills, reluctance to learn, and resistant to change are causes that make performance of students does not good in a view of process.
- Lecturer: Lecturer also can be the cause of GPA below 3, Even though student can be co-worker but student also have customer side that lecturer also should give attention. Lack of interest in change and lack of awareness of student demand are causes students' low performance.

2. Milieu

- Academic Environment: The environment of academic influences mentality of student to achieve academic success. Lack of incentive to improve, low expectation and lack of administration support are causes that make performance of students does not good in a view of process.
- Social Environment: The environment of social also influences mentality of student to achieve academic success. Family issues and culture are causes that make performance of students does not good in a view of process.

3. Method

- Materials for study: There is a chance that causes student could not achieve GPA above 3 because of students does not understand the material. It causes of the students does not ready to the material of study because of the previous requirement of study have not mastered or lack of skill academics.
- Exam Question: Exam question is the importance factor that determined if the student can get GPA above 3 or not. Mostly, the assessment gives by lecture 60% from the result of exam. Therefore, It is quite importance to give question based on what student have learned and provide proper instruction.

4. Management

- Lack of coordination: Lack of coordination in management can be causes the GPA of student below 3.Management process could not support core process to deliver value of education. Hence, it can trigger misscommunication and missunderstanding among students, lecturer, and management.
- Lack of visibility: Visibility in management is one of many factors that can improve the students' GPA. Students need to know how to apply courses, schedule of courses, complaint about the result of course and clarity on the distribution percentage assessment result. Hence, the students can prepare strategy to achieve good GPA clearly without ambiguous result.

4.2.6 Improve

After identifying the root cause of the problem GPA below 3, it is necessary to implement the action plan setting quality improvement with one of the tools in Six Sigma with 5W + 1H (What, Why, Where, When, Who, and How). The actions are as follows:

1. What (What dominant factor into the cause of the GPA below 3 of students)?
   The dominant factor that causes a GPA of student below 3 is due to the student itself. Students have 4 sub-root causes influence GPA that are lack of time, lack of knowledge & skills, reluctance to learn, and resistant to change.
2. Why (Why the improvement plan needs to be implemented and completed)?
   Plans for improvements need to be implemented in order to avoid more GPA below 3, thus improving quality of graduate students and reach the level of capability and process.
3. Where (Where a plan for improvement that needs to be done)?
   Plans for improvements made to students directly related to courses that most difficult to get good grade in Industrial Engineering Department International Program University Islamic Indonesia.
4. When (When is a repair plan to do)?
   Plans for repairing should be done immediately once the semester is completed, so for the incoming batch, GPA below 3 can be reduced.
5. Who (Who is doing the corrective action)?
   Undertaking the plan for improvement, is the lecturer who has given the task to student deliver knowledge and give grade to the student.
6. How (How to proposals for improvements to be made)?
   Steps to resolve; preferably before entering the process of education period truly make improvements by explaining what things that will be restricted in process education and providing an agreement between the faculty and students about the spread of grades so that students can prepare strategy to get good grades in order to reduce the level of students have GPA below 3. GPA below 3 that occurs during the process education from semester 1 to 8 could result the quality decreasing in IP IE UII.

CHAPTER V

DISCUSSION

This study was conducted in order to give some shed of light to implement Lean Six Sigma integrate with Business Process Management. This integration two methods use as a means of to improve quality of graduates. It gives organization a helicopter view to problem that organization faced. Earlier research suggest that there are benefits integrating Lean Six Sigma with Business Process Management like increasing effectiveness and efficiency of project improvement (Schume, 2013; Skalle & Schuster, 2008).

From Figure 4.1 can be seen that process in Industrial Engineering University Islamic Indonesia divided to be four keys cores process and one management & support key process. All of this process supported each other to improve quality of graduates in industrial engineering to fulfill requirement that needed by stakeholder in this higher education. According to (Pyzdek, 2003), Instead of the organization only have managers, organization should have process owner to avoid functional-centered and shift the organization culture to be process centered. Process centered is needed by organization as an awareness that every aspect in higher education should be accomplished with teamwork in every department instead of focus only their own department result.

This process identification from BPM method helps LSS to focus in project that have significance improvement related to issue quality of graduates. It supports processing data in define and measure phase in DMAIC phases cycle. From this process identification, it helps to make SIPOC diagram in industrial engineering University Islamic Indonesia that can be seen in Figure 4.2. From this SIPOC diagram, it can be conclude that the variation of the output can be causes by the process itself or input. To minimize this variation, higher education should have identification the capability of student so that student can be catch a study and graduate on time. In industrial engineering, students that have lack of skill

mathematic should give additional class to improve basis of knowledge in mathematic or management leveraging the difficulty of test to enter Industrial Engineering University Islamic Indonesia. But the second choice is not popular in economic perspective views because it can reduce profit from student enrollment. Therefore, commitment to maintain quality of graduates from management should be build before to take this risk.

From this SIPOC diagram, CTQs determined by the researcher that are GPA below 3, student retention, and lateness graduation. Table 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, show student Industrial Engineering Department IP UII batch 2007 – 2012 and attribute data CTQ quality of graduates. This data obtained from information technology service UNISYS. UNISYS is a website that provides student academic information and is also used to key-in KRS will students encounter every semester. From this UNISYS, the researcher elaborates information to extract data that can be used as CTQ. This UNISYS is expected to be a initial of implemented BPM in automation phase. It can be seen as BAM (Business Activity Monitoring) for manager or process owners to support decision or regulation that can improve and achieved organizational objective.

After define problem that faced and CTQs from stakeholder, researcher going to measure phase. Measure is the stage for measuring the current conditions related to the process in Industrial Engineering Department. The measurement process is performed to measure the condition of the system related to the fulfillment of the CTQ have been set at the previous stage. Pre-processing is done by measure the number of defects that occur each semester. Defect is defined as the result of any process that does not meet provisions of CTQ's. The proportion of defects use to determine the level of the upper control limit, mean and lower control limit, by creating a p Control Charts. Table 4.8 -4.23 and Figure 4.4 - 4.25 show p Control Charts each semester for data defect of the students in batch 2007 and 2012. In batch 2008, 2010, 2011, and 2012, special causes happened in semester 8. So that, it needed to recalculate statistical process control with remove the special cause process. The special causes occur because of the amount defect in semester 1 to 7 too low for possibility defect in semester 8. It occurs because the amount of defect in lateness graduation too high so that beyond UCL this p chart.

In analyze phase, researcher see and analyze the result of measure batch 2007 – 2012 in a holistic view. From Figure 4.26, it can be seen that the smallest level of

capability Sigma during batch 2007 – 2012 that is in batch 2009 amounted to 2.144587772, which will be used as a baseline measure of performance for additional improvements. Even though batch 2007 has the highest number of defect but 2009 still has low process capability because of the number of student inspected in batch 2009 decreasing with increasing amount of student attrition. From the graph above also can be concluded that the level of sigma in batch 2009 still below traditionally companies accepted that are 3 or 4 (Pyzdek, 2003). Another findings that researcher get from measure phase is process capability index of attribute data. This process capability index is analyzed from batch 2007 – 2012 that shows in Table 4.24 and Figure 4.27. It showed that the value of Cp is varying on every batch from 2007 until 2012. It means that, there is a chance or potential quality that Industrial Engineering graduates get considering how input, process, and output happened in this batch. Thus if the management wants to improve process capability to produce graduates that fit based on process condition stable, common variations common causes inherent in the process should be reduced, so that needs to be improved its performance by improving the process. Before the management improve the Cp and Sigma capabilities IP IE UII student, It is needed to determine what kind of project should management does that give significance benefit. The project conducted based on the kind of CTQ's that want to improve to meet quality requirement. In this research, there are 3 CTQs that determined based on that possible to collect that are GPA below 3, Lateness Graduation, Student Attrition. Amount of 3 CTQs will show in the Table 4.25. From the Table 4.25, it can be seen that the highest defect come from batch 2007 and the lowest come from 2008. It means that highest amount CTQs does not always show lowest Sigma capabilities and Cp.

After that, the management should decide 1 from 3 kind of defect that should be conduct project that give significance improve. Therefore, management determined percentage critical to quality potential of industrial engineering graduates in table 4.26. After calculating the percentage of the critical to quality of engineering graduates as shown in Table 4.26, then researcher created the Pareto diagram to determine the significance student defect to make a project identification and proposed improvement. Figure 4.28 shows a Pareto diagram critical to quality graduates industrial engineering defects. From the figure 4.28, it can be seen that the dominant factor defect in the 2007-2012 batch is GPA below 3 around 343 defects

(73.29%), the second one is around 91 lateness graduation defects (19.44%) and the last is student attrition around 34 defects (7.26%).

Further analysis is conducted using Fishbone diagram. Fishbone diagram used to find the root of the problem based on the determinants of quality that led to decreasing quality in Fishbone diagram. In this analysis, GPA below 3 choose to be analysis in Fishbone Diagram due to the highest significance improve based on the Pareto diagram that has been conducted. From this type of defect, it can occur due to several factors, such as Man, Method, Milieu, and Management. From these factors, it can be identified source and root cause of defects. These factors further illustrated in the fishbone diagram shown in Figure 4.29. From this fishbone diagram, it can be conclude that the most root causes for GPA below 3 is the man itself especially for student. Hence, management should do improvement to remove these root-causes of student so that the amount of GPA below 3 can be reduced.

After identifying the root cause of the problem GPA below 3, it is necessary to implement the action plan setting quality improvement with one of the tools in Six Sigma with 5W + 1H (What, Why, Where, When, Who, and How). This tool is use in improvement phase in this DMAIC phase.

CHAPTER VI

CONCLUSION & RECOMMENDATION

6.1 Conclusion

Based on the results of the collection, processing, calculations and data analysis has been done before, it can be concluded as follows:

1. From the result of calculation that get in batch 2007 – 2012, it found that the highest level of DPMO around 262,587 and the smallest Sigma level capability around 2.1 (below the traditionally company). It means that the quality of graduates in department industrial engineering is bad based on the CTQs. This is caused by a number of student defects especially in GPA below 3. One of the dominant factors that causes this problem according to fishbone diagram is a man itself especially student. This result of this DMAIC phases supported by process identification, process discovery, and process redesign from business process management method. Researcher has identified in process identification that there are 4 cores process and 1 support and management process in industrial engineering university Islamic Indonesia.

2. The suggestion from result of this 2 integration method is to improve business process before enter the process education period and make improvements by explaining what will and restricted to be learned in a course and provides an agreement between the faculty and students about the spread of grades so that students can prepare strategy to get good grades in order to reduce the level of students have GPA below 3. Because student as a raw material that need to be educated to be more valuable and knowledgeable also can be considered as

customer and co-worker in this business process.

6.2 Recommendation

Here are suggestions recommended by the researchers based on research that has been done is:

1. Beside UNISYS as academic information for stakeholder in university, it should also be used as initial business process management system (BPMS). Hence, manager can be supported by this BPMS to conduct a project improvement or making a new regulation.

2. For further research, In process identification should include determining key performance index (KPI) for every process so that manager and process owner can focus to a project that needed most improvement to achieve organizational goals

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3.1 Flow of Research

1. Determine the topic of study

Determination of research topic based on the specialization areas of research topic which is then tailored to the needs of companies and the result of consultation with the supervisor. The result of this research is directed to quality management in higher education so that the quality can meet the requirements customer higher education. In order to make a theoretical basis and state of the art in this topic of study, literature study is used as input to determine the topic of study. There will be elaborations of the literature studies that are in the form of inductive and deductive study. Inductive study is the previous study that will be the basic of research. While deductive study is the theoretical basis for supporting the problem solving in the research. Inductive study was obtained from the journal and proceeding is published periodically. While deductive study was obtained from the study of textbooks related to the theory

2. Problem Identification

After determining the topic of study, the next stage is to identify the problem. Based on the background, the quality of graduates became one of the most vital in the business processes of a higher education, Therefore, to be able to survive and continue to compete in the industrialized world, the higher education needs a repair to reduce processing time, non-value added or the existing waste in the higher education, because it also very closely related to the bottom line higher education. In addition, when a higher education produces graduates, then not all of graduate is having quality. It will definitely experience bad quality defects. To that end, researcher aim to design improvements in the quality higher education process in University Islamic Indonesia in order to reduce the number of defective graduates using concept of Lean Six Sigma and Business Process Management.

3. Problem Formulation

Problem formulation is conducted in order to direct the research to resolve the existing problems. The formulation of this problem will also be used to draw conclusions.

4. Data Collection

Data collection is conducted through interviews and observation, as well as higher education documents related to the research topic. As the cornerstone of quantitative, used historical data result academic process student in UNISYS from batch 2007 until 2012 to identify the problem and measure the performance of the initial process. Furthermore, observations and interviews is conducted to formulate a process flow for a academic process that is running and the constraints that occur. This two phases, measure and analyze, supported by business process management method that is process discovery.

5. Data Processing

Data processing was based on the Lean Six Sigma method with DMAIC phases leveraging by Business Process Management. At this stage, it sets to focus problem and measurement problem. Determination of problem focus accomplished by process identification conditions. Furthermore, from the determination of the focus problem and the existing data, measure phase is conducted to determine, process capability, sigma level, statistical process control, and a map of the current process at time. After that, the researcher going to analyze phase to determine the baseline of the current process and identify the significance defect with root cause of the problem. And the last, researcher is conducting improve phase supported by process redesign from business process management method.

6. Discussion

Discussion is about implications of the findings. It starts specifically by explaining what the results show in relation to the project, then widens out to say what this mean for the field of research as a whole.

7. Conclusion & Recommendation

At this stage, the conclusion and recommendation explain in detail about the response of the formulation of the problem formulation that was created at the beginning of the study. It also gives the right advice that can be used and developed both for higher education and further research.

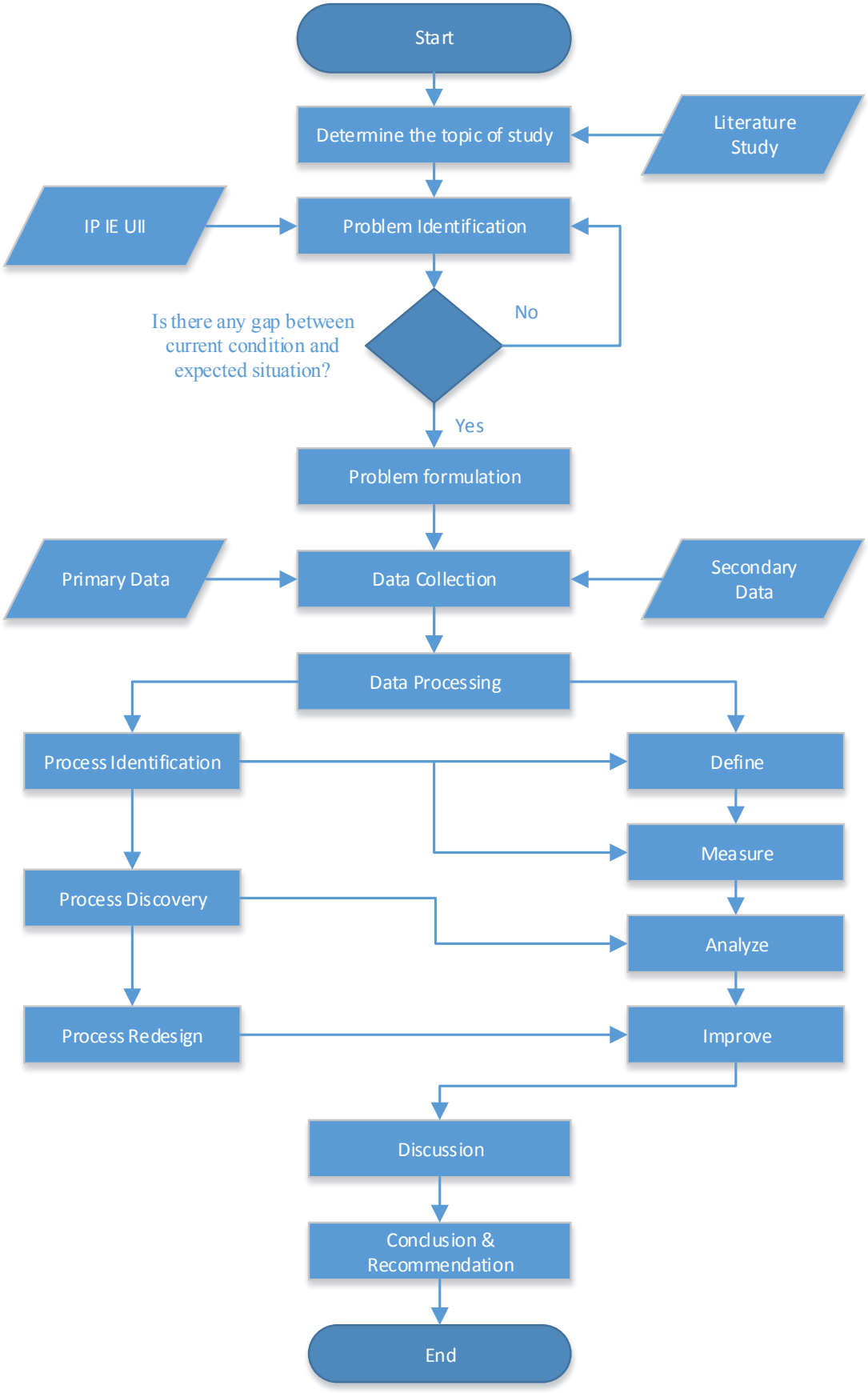
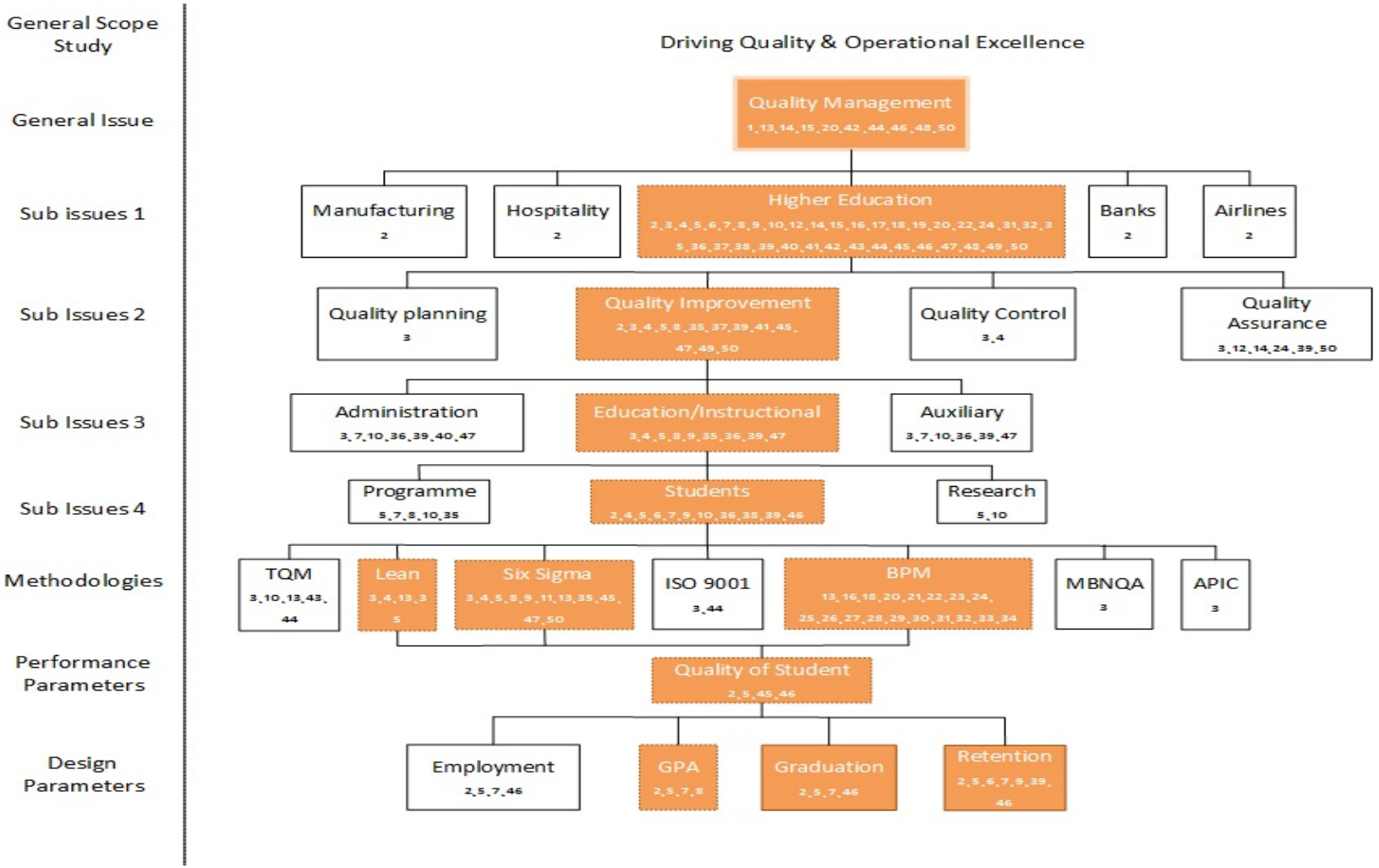


Figure 3.1 Flow of Research


General Scope Study
General Issue
Sub issues 1
Sub Issues 2
Sub Issues 3
Sub Issues 4
Methodologies
Performance Parameters
Design Parameters
Driving Quality & Operational Excellence
Quality Management
1,13,14,15,20,42,44,46,48,50
Manufacturing
2
Hospitality
2
Higher Education
2,3,4,5,6,7,8,9,10,12,14,15,16,17,18,19,20,22,24,31,32,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50
Banks
2
Airlines
2
Quality planning
3
Quality Improvement
2,3,4,5,8,35,37,39,41,45,47,49,50
Quality Control
3,4
Quality Assurance
3,12,14,24,39,50
Administration
3,7,10,36,39,40,47
Education/Instructional
3,4,5,8,9,35,36,39,47
Auxiliary
3,7,10,36,39,47
Programme
5,7,8,10,35
Students
2,4,5,6,7,9,10,36,38,39,46
Research
5,10
TQM
3,10,13,43,44
Lean
3,4,13,35
Six Sigma
3,4,5,8,9,11,13,35,45,47,50
ISO 9001
3,44
BPM
13,16,18,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34
MBNQA
3
APIC
3
Quality of Student
2,5,45,46
Employment
2,5,7,46
GPA
2,5,7,8
Graduation
2,5,7,46
Retention
2,5,6,7,9,39,46

1. (Eymen et al., 2016)
2. (Stanislav & Willborn, 1997)
3. (Quinn et al., 2009)
4. (Pavlović et al., 2014)
5. (Mazumder, 2014)
6. (Cuseo, 2012)
7. (Ramist, 1981)
8. (Kukreja et al., 2009)
9. (Hargrove & Burge, 2002)
10. (Primiani Novi C. & Ariani Wahyu D., 2005)
11. (Manuela et al., 2014)
12. (Nakhai & Neves, 2009)
13. (Grzibowska & Islam, 2011)
14. (Narimantas Kazimieras PALIULIS Rimvydas LABANAUSKIS, 2015)
15. (Faganel & Dolinsek, 2012)
16. (Duarte, 2014)
17. (UNESCO, 1998)
18. (Martins, 2007)
19. (Hall et al., 2012)
20. (Dragan et al., 2014)
21. (Recker, 2006)
22. (Barn & Oussena, 2009)
23. (Trkman, 2010)
24. (Cerverón-lleó et al., 2014)
25. (Dale & Lee, 2009)
26. (Heravizadeh, 2009)
27. (Rensburg, 1998)
28. (Bek, 2014)
29. (Röglinger et al., 2012)
30. (Yakovlev, 2015)
31. (Ibrahim, 2015)
32. (Reiner, 2012)
33. (Gerhardsson & Akerlund, 2012)
34. (Grela, 2014)
35. (Bargerstock & Richards, 2015)
36. (Taiwo, 2010)
37. (Rice & Taylor, 2003)

38. (Edler, 1997)
39. (Crosling et al ., 2009)
40. (Ward, 2009)
41. (Silva & Cabral, 2010)
42. (Owlia & Aspinwall, 1996)
43. (Owlia & Aspinwall, 1997)
44. (Csizmadia, 2006)
45. (Arafeh, 2016)
46. (Zilli, 2014)
47. (Bandyopadhyah & Lichman, 2007)
48. (Milisiunaite et al., 2009)
49. (Thalner, 2005)
50. (Sabir et al ., 2015)

2.2 Deductive Study

2.2.1. Quality in Higher Education

According to the book Managing for Quality in Higher Education (Ben & Robert, 2012) educational environment, however, is constantly in a state of flux. In such environment, competition for both students and funds will continue to increase at a time when more results are required with fewer resources. No matter how good these institutions are now, or how good they have been, they need to be even better in the future if they are meet the needs of a rapidly changing world. Institutions of higher learning need to act proactively and initiate positive, quality-focused and learner-centered programs. To achieve this end, they need an improvement model that examines each and every process in order to promote continued and permanent reform.

Ben & Robert said that the reformation of higher education demands a model for quality improvement with proven success similar to one tested and practiced in business and industry but adapted to the unique needs of academia. Educational institutions need to pursue quality consciously by systematic means. There are several reasons why a study of the applications of the theory of quality management in higher education is justified. First, quality management in higher education is still warm research activity. In fact, quality in itself is still a significant field for research.

Second, quality management is not only compatible with educational reforms but actually builds the case for them. It support educators own change goals, responds to barriers like those found in schools and helps school learn. Third, quality management is a paradigm capable of integrating several diverse higher education reform movements (e.g., accreditation or input-based approach and outcomes assessment approach) so that these attempts at reform can make their optimal contributions.

In this book also said that quality improvement defined as continuous improvement of processes is, on one hand, still new to higher education and, on the other, a deeply ingrained tradition. In the early part of the last century, institutions of higher education determined that quality could be assured by controlling process inputs like the credentials of faculty, the ability of incoming students, library holdings, and individual teacher assessment of student performance. This reliance on process inputs, however, has not been adequate to assure quality. The same was true with the movement that emerged during the latter part of that century in response to declining standards in schools. Test of one kind or another have been administered to identify deficient students and to prevent them being passed through. Educational institutions went beyond reporting on resources, structure, faculty credentials, and library holding to assess the educational results in terms of student attainments. Although this outcomes-based approach had its merits, it has not adequately assessed results of processes to determine if they were properly orchestrated. The quality management approach takes care of this gap by taking a holistic approach to assuring quality of inputs, process, and outcomes.

Ben & Robert in his book describes that the current state of quality can be described in term of three variants: compliance-oriented, improvement-oriented, and business-management oriented. These variants, which need to coexist, must be managed well in order for the organization to succeed.

- Compliance Oriented

This picture of quality focuses primary on meeting specifications, developing procedures, providing documentation, and ensuring consistency. It also involves establishing standards based on customer requirements, needs, and expectations, and ensuring that these standards are met, current nonconformance corrected, and potential future nonconformance prevented. Customer-oriented quality is often applied to manufacturing although it can also be applied to service industries. It

developed with the introduction of statistical quality control (SQC) and statistical process control (SPC). The primary goal of SQC is to monitor and control variation in the product being produced and in the service being provided. It relies on statistical charts to monitor and control product variables and on a acceptance sampling in place of one hundred percent inspection. SPC, on the other hand, focuses on the prevention of defects by applying statistical methods to control the production process. This shifts the emphasis from utilizing statistical control methods to inspect or detect poor quality to using them to prevent poor quality. With prevention, the process, rather than just the product, is monitored, controlled, and adjusted to ensure correct performance. The responsibility for quality falls on the designers and manufacturers instead of inspectors. SQC also seeks to produce parts as close to the "nominal" values as possible instead of simply trying to meet specification limits. In this service sector, SQC strives to provide services of consistent quality from customer to customer.

- Improvement Oriented

Improvement-oriented quality also known as Total Quality Management (TQM), emphasizes continuous process and system improvement to achieve customer satisfaction and ensure long-term organizational success. It promotes an integrated process improvement, and a team-based approach to problem solving and product improvement. The TQM approach encourages a long-term, never ending commitment to process improvement. It is adaptable while it seeks to meet the changing needs, requirements, and expectations of customers. Improvement-oriented quality has a wide range of applications from manufacturing, to service, and to support operations.

- Business Management Oriented

This form of quality calls for an integrated deployment of strategy and careful attention to critical success factors. This orientation, which is broader in scope, encompasses the other two described above. It requires a comprehensive vision of the business, and a broad understanding of its markets, its core processes, its value chain, and its key success factors. Business management oriented quality calls for the genuine involvement of top-level management and every employee in integrating continuous improvement efforts into everyday business activities. This involves

developing the mission statement to support the organizational vision, which provides the basis for subsequent strategies, objectives, and decisions.

The practice of quality management is no longer new to higher education. Although quality management has proven to be successful in business and military communities, its transition to education has been somewhat gradual. It had to be adapted to the unique traditions and operations of institutions of higher education. Attempts to implement the quality management philosophy in the educational setting have met some resistance especially from academic areas. Many of those involved in higher education believe that quality is already being practiced. However, there are a number of factors in the educational scene which challenge this assumption based on this book, that are:

1. Quality, as it is traditionally defined in higher education, is being challenged by many outside academia. Many colleges and universities still hold the historic view that they are the preservers, transmitters, and generators of knowledge. This view, however, conflicts with what the general public expects of their graduates with regards to the job-related value of higher education.
2. Changing economic conditions have caused concern among the general public about career opportunities and economic well-being. There is real public concern about access to higher education as a means toward employment and economic security. In the past decades tuition and other costs associated with higher education have increased substantially except in those countries where education is heavily subsidized by the government.
3. Students, parents, legislators, employers, and other stakeholders are bringing a customer orientation to their assessment of higher education. The customer orientation has helped to facilitate the outcomes assessment movement in higher education.
4. Perception of quality in higher education has diminished. Many groups inside and outside of academia believe that this loss of confidence is partly due to the tendency of colleges and universities to protect their own disciplines and culture without sufficient regard to the requirements and expectations of their stakeholders.

5. Higher educational institutions are beginning to realize that they are operating in an era characterized by increasing complexity, novelty, uncertainty, and advances in technology never previously imagined and experienced. These forces have helped to increase the gap between the quality desired by people and the quality of products and services being delivered. Technology enabled stakeholders to compare the quality of other educational systems with their own, subsequently causing the "quality desired" curve to rise at an accelerating pace.

There are as many approaches to define quality in education as there are in defining the quality of a manufactured product or delivered service. The differences in the approaches make them very difficult to develop a common approach to educational quality. Before an assessment of quality can be carried out in higher education, it is important that its essential nature is basically understood. Although each person may have some understanding of what quality is, the concept is still difficult to explain. In many cases, quality has an elusive character and is often determined by how one believes his or her personal needs and expectations have been met. The following summarizes some of the different concepts that have been used to assess quality in higher education based on this book:

- The Traditional Concept

Quality is traditionally associated with the provision of a product or service that is unique and outstanding and which bestows special status on the owner or user. Such high standards of quality can only be achieved at a great cost to the user. In higher education, the traditional concept of quality is often associated with most people's perception of the world's top-notch universities in terms of the "distinctive and special student experience that they provide, and in terms of the graduate and research output. However, if all institutions of higher learning are to be judged by the same criteria used to judge world's prestigious universities, most would be rated poor quality. This concept of quality is therefore not much of value in assessing quality in higher education as a whole.

- Conformance to Specification or Standards

According to this concept, a quality product or service is one that conforms to a specification or standard. The term "standard" is used as a "yardstick" or a basis for measuring a required characteristic of a product or service. Applied to higher education, this definition provides all institutions an opportunity to strive for quality as different standards can be set for different types of institutions.

This model has a number of drawbacks. It tells nothing of the criteria used to set the standards. A product or service which conforms to standards may still be perceived as having low quality if the standards are not in line with what the user considers as significant. The model is essentially static in that it implies that once a specification is set it does not need to be reconsidered. This is not however the case in the real world. As society changes, specifications or standards need to be revised to reflect new circumstances. The model also implies that standards are easily measurable and quantifiable. This may not be the case in higher education where the term "standard" may be defined in a different way. When used to mean "excellence or high standard" the definition becomes unclear. It is therefore important that the term "standard" be defined and applied clearly when assessing quality in higher education.

- Fitness for Purpose

This is the definition of quality adopted by most analysts and policy makers in higher education. According to this model, quality is gauged in terms of whether or not a product or service meets its stated purpose or purposes. This definition of quality has a number of advantages over the previous ones. First, it provides a means for determining the specification for a product or service. Second, it allows for reconsideration of the appropriateness of the specification over time. Third, it allows analysis of quality in higher education at various levels.

One drawback in using "fitness for purpose" as the definition of quality is the lack of consensus of what the purposes of higher education should be. Different interest groups may have different opinions on the issue. Another question is who should define the purposes of higher education. It is also possible for higher education to have multiple purposes some of which may be conflicting with each other.

- Effectiveness in Achieving Institutional Goals

This concept focuses on evaluating quality in education at the institutional level. An institution is said having high quality if it "clearly states its mission (or purpose) and is efficient and effective in meeting the goals that it has set for itself". Each college or university determines its own definitions of quality and standards and establishes its own quality assurance system. It is then evaluated by an audit committee to check whether the institution is successfully achieving its stated aims and objectives. This model is broader than the "fitness for purpose" definition and includes other areas such as effective management and resource usage efficiency in the evaluation of quality in higher education.

- Meeting Customers' Stated or Implied Needs

This definition of quality places high emphasis on identifying and meeting customers' needs. The customers' future needs are translated into measurable characteristics and then products or services are designed and delivered at a price the customer will pay. A number of difficulties arise from defining quality as meeting customers' needs particularly in higher education. Questions remain as to who is the customer of higher education or who should define quality in higher education. Taking the student as the customer poses a number of difficulties. Although students' needs can be easily identified and met, the quality of student experience goes beyond this. Lectures and students are both parts of the production process and are both producers and customers depending on the circumstances. Consequently, the standards of quality are difficult to state and to maintain. Another criticism is that students or customers in general may not always be placed to determine what quality is or whether it is present.

- A Practical Definition of Quality for Higher Education

There is no single, all-encompassing definition of quality that meets the needs of all stakeholders in higher education. Different interest groups have different priorities and needs. Although their understanding of quality may differ, they may not necessarily be right or wrong. Quality therefore should not be considered as a unitary concept but a multiple one. Based on this concept, a school which may be considered

a high-quality institution when evaluated according to one factor may be a low-quality one when gauged by another.

Towards the end of the 1980s, many companies have come to embrace a more customer-driven definition of quality. Quality has come to be defined as meeting or exceeding customer expectations. In order to comprehend this definition, one must first understand the meaning of the term 'customer'. Most people think that the customers are the ultimate purchasers of the product or service and are more specifically referred to as consumers. But before a product reaches the consumer, it may first flow through a chain of many firms or departments, each of which adds some value to the product. This type of customers may be referred to as external customers. It is also important to point out that every employee in a company also has internal customers who receive goods or services from suppliers within the company. Thus, understanding who one's customers are and what their expectations are is key to achieving customer satisfaction.

In higher education, Faculty and Administrators alike are reluctant to call a student or anyone else a customer. Many faculty members feel threatened by the notion that students are customers of the educational process. The idea that students (customers) are partners in developing and delivering quality education (the product or service) threatens the historic, traditional academic role of faculty as purveyor of knowledge. Many educational institutions are very hesitant to consider themselves as customer-driven entities. Customer-driven organizations are effective because they are fully committed to satisfying, even anticipating customer needs. The future success of colleges and universities will increasingly be determined by how they satisfy their various customers. The successful ones will be those which very clearly identify their mission and the customers they serve said by Ben & Robert.

In order to understand customer needs, an organization must first identify who its customers are. Often customers are classified as internal or external. They are the ultimate ones we are trying to satisfy with our work. The final recipient of a product or service is commonly referred to as the end-user or just plain consumer. Below are the classification customer in higher education based on (Ben & Robert, 2012) book:

- Internal Customers – Academic

a. Students

They are usually considered the most important internal customers of higher education. Students usually enter school with the desire to acquire skills, to gain knowledge and learn about the world around them. They need to develop the confidence and drive to pursue their dreams and desires. They also need to experience joy in learning both within the classroom as well as within the whole school environment. Within the academic environment, students are unique in the sense that they assume different roles each of which has a different implication for improving the process of learning.

- *Raw material,* this view suggests that we must understand students' backgrounds, attitudes and differences in academic preparation. This does not imply that students are passive recipients of the learning process. On the contrary, this view helps us to be more understanding of students and to be more sensitive especially to the differences in their preparation for the higher learning process.

- *Work in process,* once students are admitted, they go through a sequence of courses required for their degree. They are tested and graded at the end of each course and throughout the course of their academic programs.

- *Products,* this view helps us to focus on the result of the students' educational process and identify the relevant skills and information that they will have upon completing the process of course. This product view does not suggest that students are passive recipients or outcomes of the learning process or methods. Rather this view aids us to match course content and activity with the desired educational outcomes.

- *Co-workers,* this view compels us to look at the course being taught as a collaborative undertaking and solicit student input when designing and redesigning course requirements and processes

- *Customers,* Students are appropriately viewed as customers in the sense that they are beneficiaries with needs that should be satisfied. This view does not imply that they are the ultimate arbiters of quality in the commercial sense. We recognize that many of them when they enter college or university do not have a

good understanding of what is best for their professional preparation. However, students are well-equipped to evaluate an educational delivery system, although they may not be qualified to give input as to its content.

The status of students within the academic program is somewhat unique. Their ability to interact with the rest of the system further complicates the relationship that exists between them and their professors. When it comes to the delivery of knowledge, instructors are the suppliers and students are the receivers-customers. But students are also expected to learn the material presented by their professors, do assignments, complete projects, and prepare for test. In this part of the academic process, students function as co-workers or co-laborers. Thus, no one should be surprised if students are quite happy when classes are cancelled or dismissed early. When it comes to this matter, students do not behave like typical customers. Their co-worker role outweighs their customer role.

b. Faculty

Teachers are entrusted with the solemn responsibility of preparing the students of this nation for the future. They deserve recognition and respect for what they do and less blame for what the system does or fails to do. Teachers need continued professional growth opportunities and tools and autonomy to accomplish their tasks and experience joy in work. Such opportunities will greatly enhance their self-esteem and allow them to have pride in their work. Also, professors teaching particular classes require that students have adequate background in the prerequisite courses. Perhaps one of the most pressing needs of teachers today would be adequate compensation for their work besides recognition and respect.

c. Programs or departments

The academic subsystem, as part of the larger system of higher education, consists of its own set of input resources, the transformation process, and outputs. Its resources include, but are not limited to, students, faculty, staff, library, computing and laboratory facilities, and other facilities. The transformation process consists of activities done to disseminate knowledge, to conduct research, and to provide community service. It is in the transformation process where interactions among input resources occur. Thus, the need for cooperation and collaboration between programs

or departments in the performance of the various tasks. Effective communication and information exchange is also necessary within the academic subsystem and between the academic system and the administrative subsystem. The outputs of the academic process are educated people, research and publications, and service to the community. Programs or departments need to be engaged in the never-ending process of quality improvement.

- Internal Customers – Administrative

a. Students

They are clearly the primary internal customers of many facilities in the campus. For instance, students pay for the use of many facilities such as dormitories, food services, bookstores, libraries, gymnasiums, security services, and others. These facilities help to attract better students, provide a more satisfactory campus climate and support the academic programs of the institution. In the nonacademic setting, students should be treated as typical customers by providing them services when they request for them, and answering their queries when they ask for assistance.

b. Faculty

Teachers benefit from the use of certain facilities in the campus like the bookstore, the library, the computer store, the postal office, the health club, the swimming pool and other campus facilities. Also, they benefit from services offered by other departments like the Human Resources office, the transportation department, the administrative offices, and others. Teachers expect that they be treated as typical customers by providing them services which are requested and by answering their queries promptly and accurately.

c. Non-teaching staff

The needs of the non-teaching staff are to a great extent similar to those of the faculty. They seek continuous personal growth, security, and joy in work. They need to be kept informed and involved and shown how they are part of the bigger system of higher education. The institution must help them develop and realize their potential in

pursuing their quality and performance objectives. They should be considered as assets to be developed rather than expenses to be controlled.

d. Administrators

Like the faculty, administrators expect improved professional status, proper recognition for their work, and reasonable compensation for their efforts. To perform their job more effectively, they need support and feedback from all constituents of the educational system in providing constructive solutions to common problems faced by the institution.

e. Units. Departments or divisions

The needs are similar to those of programs or departments in the academic subsystem. Units, departments or divisions within the administrative subsystem must work as a team together and in conjunction with the programs and departments in the academic subsystem. Barriers between them should be broken down to allow for effective communication and information exchange. They must be engaged in the never-ending process of quality improvement.

- External Customers – Indirect

a. Government

Federal tax policies affect higher education in terms of research support and financial support for students attending colleges and universities. As a condition for federal spending and tax support, the legislative and executive agencies of the government impose a variety of rules and mandates on both institutions and students. The impact of the federal government on higher education is substantial, diverse, and constantly changing.

The state governments are a major source of funding for their respective state institutions. Thus they have a legitimate interest in the responsiveness of higher education to major societal needs. While institutional autonomy is important, there is a need for a constructive relationship between the college/university and the state. Higher education needs to recognize that it has a stake, if not responsibility, to engage with state political leaders regarding the nature of their relationship. This includes defining those societal goals toward which the college or university should direct its energies and shaping the policies which govern such relationship.

b. Community

The support of the community is crucial to the success of the operation of higher education. Community outreach and programs strengthen overall institutional effectiveness in preparing tomorrow's student for lifelong involvement. It has been found that university support for student and faculty opportunities to volunteer and perform community service leads to enhance civic responsibility. Besides providing volunteer services, colleges and universities are expected by their communities to contribute to the development of a competent workforce, the training of leaders and followers, and the nurture of politically active and civic minded citizens.

c. Donors

The process of asking for gifts begin by informing potential donors of the social need being met by the organization, involving them in the work of that organization and then inviting them to invest financially in that work. The donor usually offers something of value to the organization for a variety of reasons, without expecting any material or monetary return. Of course, donors expect that they be informed about the legitimacy of the need and be given appropriate acknowledgement for making a donation. The college/ university can acknowledge the gift by recognizing donors for their support of a worthy cause, by helping them feel that they made a difference in the resolution of a problem and giving them a sense of ownership in a program that serves the public good.

d. Alumni

In many ways, the college or university connects with the society at large through its alumni. The real success of its programs is often judged by how well its alumni represent its values in their everyday lives and in their lines of work. One way this connection can be strengthened is through programs which bring alumni to the campus in a participatory way. It is also a known fact that alumni are a significant source of financial gifts for the institution.

e. Accrediting agencies

Accreditation provides public notification than an institution or program meets standards of quality stipulated by the accrediting agency. It also reflects the fact that to be recognized by the accrediting agency, the institution or program is committed to self-study and external review by one's peers in seeking not only to meet standards but to continuously seek ways in which to enhance the quality of education and training provided. Accrediting agencies expect accreditation-seeking institutions to comply with their established criteria and standards.

- Internal Customers – Direct

a. Employers

It is fairly reasonable to say that service and manufacturing industries and other non-profit organizations are the largest direct volume customers of higher education. Employers expect colleges and universities to produce well-qualified and trained graduates who could work efficiently and effectively in the jobs for which they have been hired. They need workers who have communication and problem-solving skills and are willing and able to learn their specific jobs quickly and effectively.

b. Other colleges/universities

Colleges and universities which admit students from other higher educational institutions require that these students possess enough knowledge, skills and preparation to take up further or higher studies. In other words, they want students who are capable of advanced learning and research.

c. Suppliers

Suppliers include those from whom a college or university receives students, goods, or services. Examples are high schools or academies as well as those organizations that supply goods and/or services to the college or university. Suppliers need feedback from the recipients of the goods and services that they provide in order to be able to improve the quality of their production processes. They also seek to build a long-term relationship with colleges and universities based on loyalty and trust.

2.2.2. Business Process Management

BPM is a discipline that concern about process that deliver value or things to internal and external customer and how to make the value or things visible to every client in business process. According to the book fundamental of business process management (Dumas, La Rosa, Mendling, & Reijers, 2013) said that business process as a collection of inter-related events, activities and decision points that involve a number of actors and objects, and that collectively lead to an outcome that is of value to at least one customer. Industrial engineers see BPM as an opportunity to apply well-trodden manufacturing optimization techniques in the context of organizations that deliver services rather than physical products. Figure 2.2 depicts the ingredients of this definition and their relations.

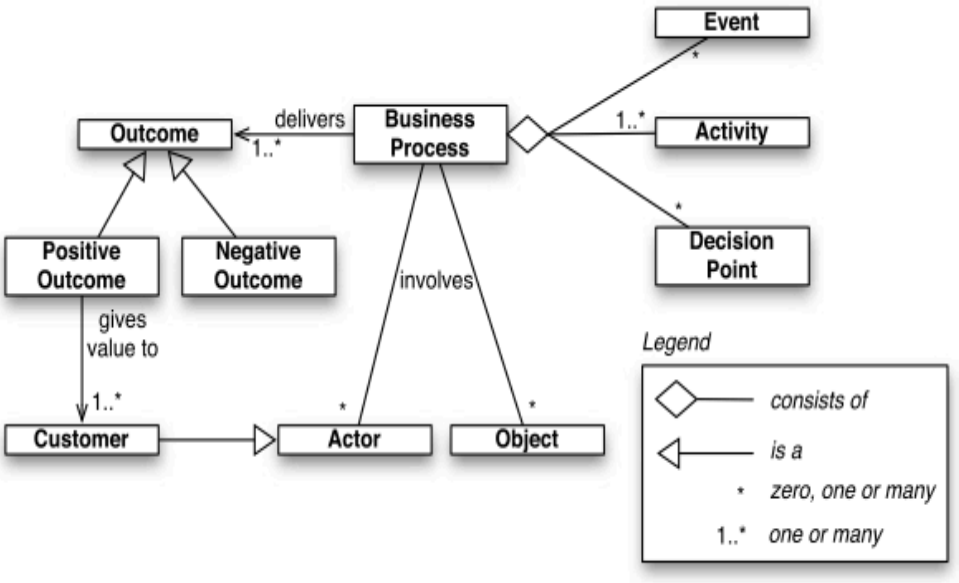


Figure 2.2 Ingredient of a business process (Dumas et al., 2013)

A business process encompasses a number of *events* and *activities*. Events correspond to things that happen atomically, meaning that they have no duration. An activity is a thing that it takes time. When an activity is rather simple and can be seen as one single unit of work, we call it a *task.* In addition to events and activities, a typical process involves *decision points,* that is, points in time when a decision is made that effects the way the process is executed. A process also involves a number of actors (human actors, organizations, or software system acting on behalf of human actors or organizations), physical objects (equipment, materials, products, paper documents) and immaterial objects (electronic documents and electronic records).

Finally, the execution of a process leads to one or several *outcomes*. Ideally, an outcome should deliver value to the actors involved in the process but in some cases, this value is not achieved or is only partially achieved. This corresponds to a *negative outcome*, as opposed to a *positive outcome* that delivers value to the actors involved. Among the actors involved in a process, the one who consumes the output of the process plays a special role, namely the role of the *customer*. Sometimes, there are multiple customers in a process. For example, in a process for selling a house, there is a buyer, a seller, a real estate agent, one or multiple mortgage providers, and at least one notary. The outcome of the process is a sales transaction. This outcome provides value both to the buyer who gets the house and to the seller who monetizes the house. Therefore, both the buyer and the seller can be seen as customers in this process, while the remaining actors provide various services.

Armed with this definition of a business process, we define BPM as a body of methods, techniques and tools to discover, analyze, redesign, execute and monitor business processes. This definition reflects the fact that business processes are the focal point of BPM, and also the fact that BPM involves different phases and activities in the lifecycle of business process. The way processes are designed and performed affects both the "quality of service" that customers perceive and the efficiency with which services are delivered. An organization can outperform another organization offering similar kinds of service if it has better processes and executes them better. This is true not only of customer-facing processes, but also of internal processes. Any business would ideally like to make its process faster, cheaper, and better. This simple observation leads us already to identifying three process performance dimensions: time, cost and quality. The quality of a business process can be viewed from at least two different angles: from the customer side and from the process participant's side. This is also known as the distinction between external quality and internal quality. The *external quality* can be measured as the customer satisfaction with either the product or the process. Satisfaction with the product can be expressed as the extent to which a customer feels that the specifications or expectations are met by delivered product. On the other hand, a customer satisfaction with the process concerns the way how it executed. A typical issue is the amount, relevance, quality, and timeliness of the information that a customer receives during execution on the progress being made. The *internal quality* of a business process related to the process participants' viewpoint. Typical internal quality concern are: the

level that a process participants feels in control of the work performed, the level of variation experienced and whether working within the context of business process is felt as challenging (Dumas et al., 2013).

Every organization, be it a governmental body, a non-profit organization, or an enterprise, has to manage a number of processes. Typical examples of processes that can be found in most organizations include from (Dumas et al., 2013):

- Order-to-cash

This is a type of process performed by a vendor, which starts when a customer submits an order to purchase a products or a service and ends when the product or service in question has been delivered to the customer and the customer has made the corresponding payment. An order-to-cash process encompasses activities related to purchase order verification, shipment, delivery, invoicing, payment receipt and acknowledgement.

- Quote-to-order

This type of process typically precedes an order-to-cash process. It starts from the point when a supplier receives a "Request for Quote" (RFQ) from a customer and ends when the customer in question places a purchase order based on the received quote. The order-to-cash process takes the relay from that point on. The combination of a quote-to-order and the corresponding order-to-cash is called a quote-to-cash process.

- Procure-to-pay

This type of process starts when someone in an organization determines that a given product or service needs to be purchased. It ends when the product or service has been delivered and paid for. A procure-to-pay process includes activities such as obtaining quotes, approving the purchase, selecting a supplier, issuing a purchase order, receiving the goods (or consuming the service), checking and paying the invoice. A procure-to-pay process can be seen as the dual of quote-to-cash process in the context of business-to-business interactions. For every procure-to-pay process there is a corresponding quote-to-cash process on the supplier's side.

- Issue-to-resolution

This type of process starts when a customer raises a problem or issue, such as a complaint related to a defect in a product or an issue encountered when consuming a service. The process continues until the customer, the supplier, or preferably both of them, agree that the issue has been resolved. A variant of this process can be found in insurance companies that have to deal with "insurance claims". This variant is often called claim-to-resolution.

- Application-to-approval

This type of process starts when someone applies for a benefit or privilege and ends when the benefit or privilege in question is either granted or denied. This type of process is common in government agencies, for example when a citizen applies for a building permit or when a businessman applies for a permit a business. Another process that falls into this category is the admissions process in a university, which starts when a student applies for admission into a degree. Yet another example is the process for approval of vacation or special leave request in a company.

As the above examples illustrates, business processes are what companies do whenever they deliver a service or a product to customers. The way processes are designed and performed affects both the "quality of service" that customers perceive and the efficiency with which services are delivered (Dumas et al., 2013). A process also involves a number of actors (human actors, organizations, or software systems acting on behalf of human actors or organizations), physical objects (equipment, materials, products, paper documents) and immaterial objects (equipment, materials, products, paper documents).

There are many languages for modeling business processes diagrammatically. Perhaps one of the oldest ones are flowcharts. Several extensions of flowcharts exist, like cross-organizational flowcharts, where the flowchart is divided into so-called *swimlanes* that denote different organizational units. Another languages for modeling in business process is Unified Modeling Language (UML) and Event-driven Process Chains (EPCs). UML Activity Diagrams are cross-organizational flowcharts by providing symbols to capture data objects, signals and parallelism among other aspects. EPCs have some similarities with flowcharts but they differ from flowcharts

in that they treat events as first-class citizens. Other languages used for process modeling include data-flow diagrams and IDEF3.

It would be mind-boggling to try to learn all these languages at once. Fortunately, nowadays there is a widely used standard for process modeling, namely the Business Process Model and Notation (BPMN). The latest version of BPMN is BPMN 2.0. It was released as a standard by the Object Management Group (OMG) in 2011. In BPMN, activities are represented as rounded rectangles. Control nodes (called *gateways*) are represented using diamond shapes. Activities and control nodes are connected by means of arcs (called flows) that determine the order in which the process is executed.

(Dumas et al., 2013) describes view BPM as continuous cycle comprising the following phases (See Figure 2.3)

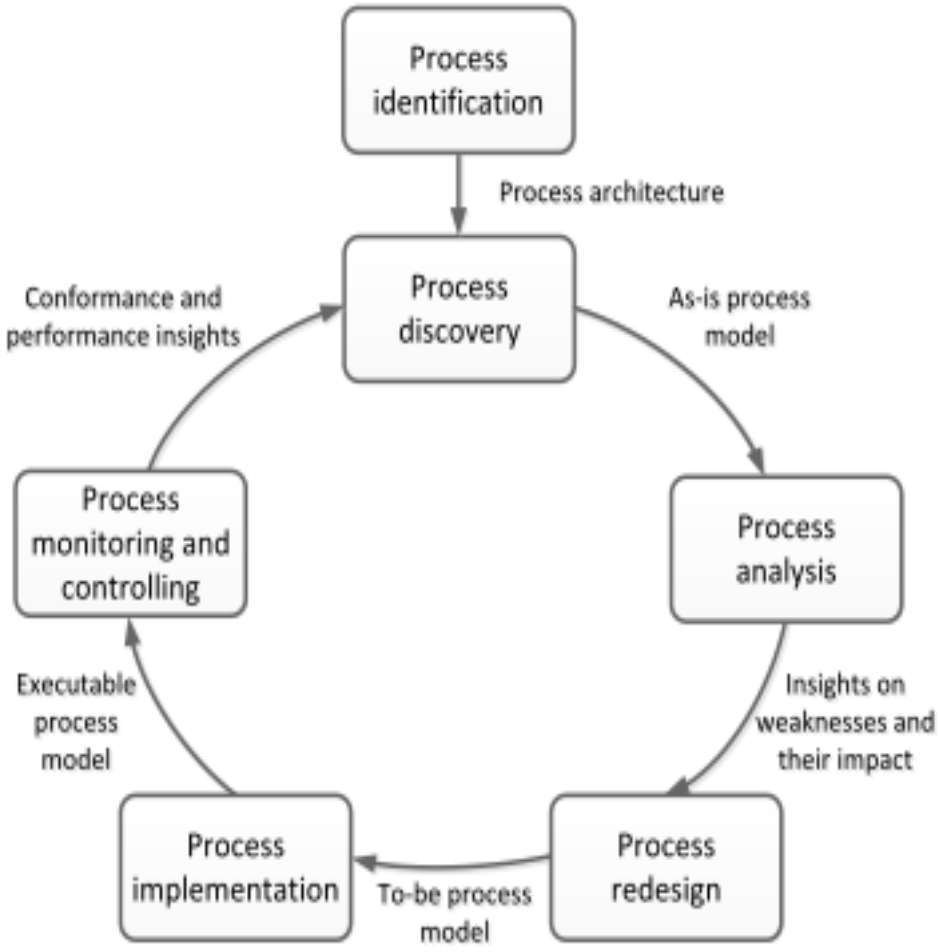


Figure 2.3 BPM Lifecycle (Dumas et al., 2013)

- Process Identification

In this phase, a business problem is posed, processes relevant to the problem being addressed are identified, delimited and related to each other. The outcome of process identification is a new or updated process architecture that provides an overall view of the processes in an organization and their relationships. In some cases, process identification is done in parallel with performance measure identification. The recurrent class of measures in the context of BPM for performance measures identification related to cost, time (cycle time), and quality (error rates). More specifically, process identification is concerned with two successive phases: designation and evaluation. The objective of the designation phase is to gain an understanding of the processes an organization is involved in as well as their inter-relationships. The evaluation phase, based on the understanding that is established in the previous phase, intends to develop a prioritization among these for process management activities (modeling, redesign, automation, monitoring, etc.).

- Process Discovery (also called as-is process modeling)

The current state of each of the relevant process is documented, typically one of the outcomes of this phase is one or several as-is process models.

- Process Analysis

In this phase, issues associated to the as-is process are identified, documented and whenever possible quantified using performance measures. The output of this phase is a structured collection of issues. These issues are typically prioritized in terms of their impact, and sometimes also in terms of the estimated effort required to resolve them.

- Process redesign (also called process improvement)

The goal of this phase is to identify changes to the process that would help to address the issues identified in the previous phase and allow the organization to meet its performance objectives. To this end, multiple change options are analyzed and compared in terms of the chosen performance measures. This entails that process redesign and process analysis going hand-in-hand: As new change options are proposed, they are analyzed using process analysis techniques. Eventually, the most promising change options are combined, leading to a redesigned process. The output

of this phase is typically a to-be process model, which serves as a basis for the next phase.

- Process implementation

In this phase, the change required to move from the as-is process to the to-be process are prepared and performed. Process implementation covers two aspects: organizational change management and process automation. Organizational change management refers to the set of activities required to change the way of working of all participants involved in the process. Process automation on the other hand refers to the development and deployment of IT systems (or enhanced versions of existing IT systems) that support the to-be process.

- Process monitoring and controlling

Once the redesigned process is running, relevant data are collected and analyzed to determine how well is the process performing with respect to its performance measures and performance objectives. Bottlenecks, recurrent errors or deviations with respect to the intended behavior are identified and corrective actions are undertaken, New issues may then arise, in the same or in other processes, requiring the cycle to be repeated on a continuous basis.

The BPM lifecycle helps to understand the role of technology organizational management in BPM. There are different stakeholders involved with a business process throughout its lifecycle. Among them we can distinguish the following individuals and groups (Dumas et al., 2013).

- Management Team

Depending on how the management of a company is organized, one might find the following positions. The Chief Executive Officer (CEO) is responsible for the overall business success of the company. The Chief Operations Officer (COO) is responsible for defining the way operations are set-up. In some companies, the COO is also responsible for process performance, while in other companies, there is a dedicated position of Chief Process Officer (CPO) for this purpose. The Chief Information

Officer (CIO) is responsible for the efficient and effective operation of the information system infrastructure. In some organizations, process redesign projects are driven by the CIO. The Chief Financial Officer (CFO) is responsible for the overall financial performance of the company. The CFO may also be responsible for certain business processes, particularly those that have a direct impact on financial performance. Other management positions that have a stake in the lifecycle of processes include the Human Resources (HR) director. The HR director and their team play a key role in processes that involve significant numbers of process participants. In any case, the management team is responsible for overseeing all processes, initiating process redesign initiatives, and providing resources and strategic guidance to stakeholders involved in all phases of the business process life- cycle.

- Process Owner

A process owner is responsible for the efficient ad effective operation of a given process. Process owner is responsible on the one hand for planning and organizing, and on the other hand for monitoring and controlling the process. In their planning and organizing role, the process owner is responsible for defining performance measures and objectives as well as initiating and leading improvement projects related to their process. They are also responsible for securing resources so that the process runs smoothly on a daily basis. In their monitoring and controlling role, process owners are responsible for ensuring that the performance objectives of the process are met and taking corrective actions in case they are not met. Process owners also provide guidance to process participants on how to resolve exceptions and errors that occur during the execution of the process. Thus, the process owner is involved in process modeling, analysis, redesign, implementation and monitoring. Note that the same individual could well be responsible for multiple processes. For example, in a small company, a single manager might be responsible both for the company's order-to-cash process and for the after-sales customer service process.

- Process Participants

Process participants are human actors who perform the activities of a business process on a day-to-day basis. They conduct routine work according to the standards and guidelines of the company. Process participants are coordinated by the process owner,

who is responsible to deal with non-routine aspects of the process. Process participants are also involved as domain experts during process discovery and process analysis. They support redesign activities and implementation efforts.

- Process Analyst

Process analysts conduct process identification, discovery (in particular modeling), analysis and redesign activities. They coordinate process implementation as well as process monitoring and controlling. They report to management and process owners and closely interact with process participants. Process analysts typically have one of two backgrounds. Process analysts concerned with organizational requirements, performance, and change management have a business background. Meanwhile, process analysts concerned with process automation have an IT background.

- System Engineers

System engineers are involved in process redesign and implementation. They interact with process analysts to capture system requirements. They translate requirements into a system design and they are responsible for the implementation, testing and deployment of this system. System engineers also liaise with the process owner and process participants to ensure that the developed system supports their work in an effective manner. Oftentimes, system implementation, testing and deployment are outsourced to external providers.

- The BPM Group (also called BPM Centre of Excellence)

Large organizations that have been engaged in BPM for several years would normally have accumulated valuable knowledge on how to plan and execute BPM projects as well as substantial amounts of process documentation. The BPM Group is responsible for preserving this knowledge and documentation and ensuring that they are used to meet the organization's strategic goals. Specifically, the BPM group is responsible for maintaining the process architecture, prioritizing process redesign projects, giving support to the process owners and process analysts, and ensuring that the process documentation is maintained in a consistent manner and that the process monitoring systems are working effectively. In other words, the BPM group is responsible for maintaining a BPM culture and ensuring that this BPM culture is sup- porting the

strategic goals of the organization. Not all organizations have a dedicated BPM Group. BPM Groups are most common in large organizations with years of BPM experience.

In addition, (Pyzdek, 2003) said that process refers to any activity or set of activities that transform inputs to create values for stakeholders. The input can be labor, expertise, raw materials, products, transactions, or services that someone is willing to pay more for than they cost to create. Many business leaders think of their organization as extremely complex. Once the basis (core) processes have been identified, the relationship between them should be determined and drawn on a process map. The process map presents employees with a simple picture that illustrates how enterprise serves its customers. It is the basis for identifying sub-processes and, eventually, Six Sigma projects.

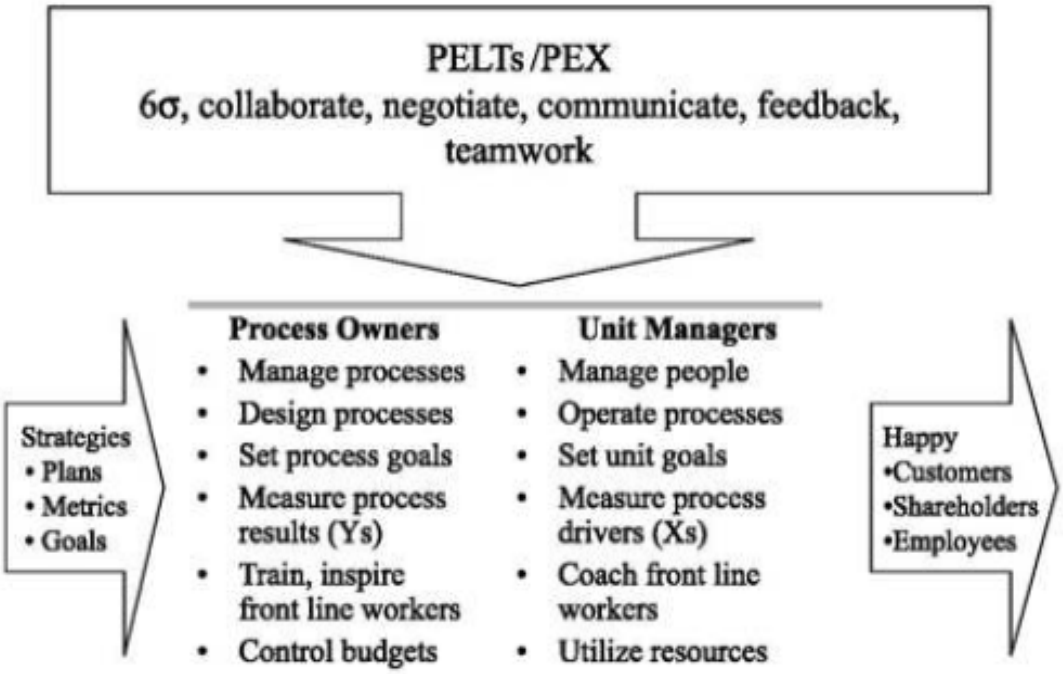


Figure 2.4 Process Enterprise roles and responsibilities (Pyzdek, 2003)

From the Figure 2.4 above, it can be seen that between process owner and unit manager have difference responsibilities. Process owner and unit manager work together through Process Excellence Leadership Teams (PELTs) to assure that the

needs of the major stakeholder groups are met. The need for inter-process cooperation highlights the fact that no process is an island. From the customer's perspective, it's all one process. Overall excellence requires that the entire business be viewed as the customer sees it.

2.2.3. Lean Six Sigma

According to book Lean Six Sigma (George, 2002), Lean Six Sigma is a methodology that maximizes shareholder value by achieving the fastest rate of improvement in customer satisfaction, cost, quality, process speed and invested capital. The fusion of Lean and Six Sigma is required because Lean cannot bring a process under statistical control and Six Sigma alone cannot dramatically improve process speed or reduce invested capital. Lean Six Sigma works not by speeding up the workers or the machines, but by reducing unneeded wait time between value-add steps. According to (Taghizadegan, 2006) Lean Six Sigma means "best-in-class" that creates value in the organization to benefit its customers. Which "Lean" is standing for speed and quick action (reducing unneeded wait time) and "Six Sigma" is standing for identifying defects and eliminating them. The process of the Lean Six Sigma model is shown in Figures 2.5

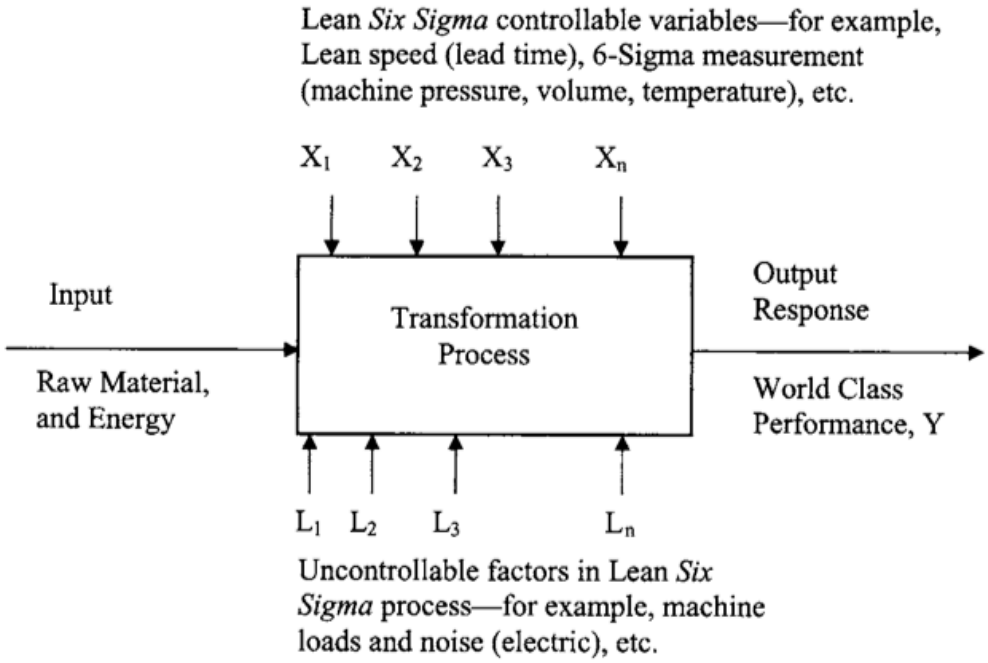


Figure 2.5 General model of Lean Six Sigma process (Taghizadegan, 2006)

Mathematically, the world class performance (WCP) is the output response defined as a function of Lean and Six Sigma. In other words, WCP is dependent on Lean (y_L) and Six Sigma (y_{SS}). Thus, as a mathematical function:

$$\text{World class performance} = f(\text{Lean causes of variation, Six Sigma causes of variation})$$

WCP equation above elaborates in equation 2.1 below:

$$\begin{gathered} Output = f(Input) \\ Y_{WCP}\ (or\ Y_{LSS}) = f(Y_L,\ Y_{SS}) = f\ [f_L(x), f_{SS}(x)] \\ y_L = f(y_1, y_2, y_3, \dots, y_{n-2}, y_{n-1}, y_n) \\ y_{SS} = f(y_1, y_2, y_3, \dots, y_{n-2}, y_{n-1}, y_n) \end{gathered} \quad \dots(2.1)$$

Where Y_{WCP} is world class performance response and Y_{LSS} is Lean Six Sigma output. Y_{LSS} is a function of the second round of measurements y_L (Lean output) and Y_{SS} (Six Sigma output). Notations $(y_1, y_2, y_3, \dots, y_{n-2}, y_{n-1}, y_n)$ represent the results

of design, process, wait time, and so on. The second round of measurements arises from causes of Lean Six Sigmam that is, overproduction, excess inventory, design issues, dimensional variation, process condition, and machine downtime, as indicated in Equation X.X:

$$\begin{aligned} y_{overproduction} &= f(x_1, x_2, x_3, \dots, x_{n-2}, x_{n-1}, x_n) \\ y_{wait-time} &= f(x_1, x_2, x_3, \dots, x_{n-2}, x_{n-1}, x_n) \\ y_{design} &= f(x_1, x_2, x_3, \dots, x_{n-2}, x_{n-1}, x_n) \\ y_{process} &= f(x_1, x_2, x_3, \dots, x_{n-2}, x_{n-1}, x_n) \end{aligned} \quad \dots(2.2)$$

Where y is response or measured values that is, symptoms of performance, production, manufacturing, and product functionality, f is a response function of Y_L (Lean) and Y_{SS} (Six Sigma) performance, $x_1, x_2, x_3, \dots, x_{n-2}, x_{n-1}, x_n$ are causes of independent variables that is, variations in wait time factors, design factors, process, and so on.

The following rules and principles are required when designing and processing for a Lean Six Sigma project to meet the world class performance criteria (Taghizadegan, 2006):

1. Apply Six Sigma concepts to define phase, measure, analyze, develop/ improve, and verify/control (DMAIC). Likewise, Six Sigma is a function of Six Sigma process measurement and improvement variables:

$$\text{Six Sigma} = f(\text{measure variables}, \text{improve variables})$$

2. Concentrate on quality and cost.
3. Focus on the company's bottom line.
4. Confirm on-time delivery, which is the customer's priority.
5. Improve productivity.
6. Emphasize safety and environment.
7. Focus on the voice of customer.
    - Match customer’s specification limits.

- Identify customer's critical-to-quality (CTQ) issues and try to meet their requirements.
- Focus on elements of Lean manufacturing: faster, better, and cheaper.
- Meet customer satisfaction with speed and quality.

8. Focus on reduction of delay time, for example, 80% of the delay in any process is caused by 20% of the activities (workstations/time trap).
9. Focus on reduction of wait time, for example, 95% of lead time (the difference between the time an order is placed and when it is delivered by the supplier) in most processes is wait time. This exceeds by far the 5% of the time that is needed to get the job done, therefore slow processes are expensive processes, as shown below:

$$Lead\ time = Time\ an\ order\ is\ received - Time\ an\ order\ is\ placed$$
$$= (processing, shipping, and\ handling) time$$

10. Improve the slow processes that are expensive and costly.
11. Apply 5s improvement (Kaizen)
12. Just-in-time (JIT)/Kanban.
13. Total production maintenance (TPM)

Furthermore, According to (Ron Crabtree, 2010), LSS identifies eight wastes. These Lean Six Sigma wastes can be identified by the acronym DOWNTIME:

- Defects.

Are you producing defects and defective products and services? Why? Dig down and root out and correct the causes. However, having a zero defects mentality will kill the initiative necessary for success in business and is completely unrealistic. The matters is the ability and willingness of your team to dig down to the root causes behind the defects, and the initiative and creativeness of your team to find and implement the solutions to fix and prevent future occurrences.

- Overproduction & oversupply

Are parts of your organization out of balance with others or with the organization as a whole? Maybe one portion of your operation is producing too much while other parts are producing too little. Do you see excess inventory piling up anywhere? The ideal in a High Performance Enterprise is Just-In-Time delivery. Strive toward having just enough supplies and materials required for each function at the time they are needed. Excess quantities indicate your process flow is being blocked.

- Waiting (time)

Are people waiting? Whether it's your customers, patients or your employees, waiting serves no purpose. There are two important time wastes we see time and time again, regardless of industry:

1. Waiting for decisions to be made, including diagnosis time; and
2. Supplies and people waiting, "just in case."

- Non-productive use of people

Are people working at their full capacity and potential? Is your management approach based on fear, demanding compliance, rather than on positive reinforcement and employee contribution? Are your people empowered or micro-managed? Do your employees feel unimportant, unheard, or as though they have little, if any, say in what they do? Do they provide constructive feedback or input about frontline operations and practices that only they can see? If individuals do not have the authority to act on their own expertise and what they observe at the time it is occurring, you will be unable to increase your organization's knowledge, flexibility and responsiveness.

- Transportation

Do you see materials or information being moved from place to place, processes to processes, adding needless time, effort and cost? Creating complex requirements for simple processes is indicative of waste. A process that requires a worker to track down managers and obtain three signatures on a document before work on a project

can begin is one example. Unnecessary transportation is often connected with inventory retrieval, but can occur anywhere in the organization.

- Inventory

Bottlenecks are a clear indication of inventory problems. These can be either human or material-related. For instance, do you see stacks of supplies waiting to be used at some later date? You might also see bottlenecks in the flow of information or project work caused by individuals or incompatible systems.

- Motion

Are employees taking unnecessary steps to do their jobs? For instance, are they constantly getting up and down to get materials to finish a task? Do you have the most efficient work layout to accomplish the task. If you answered yes to any of these questions, you might want to investigate the advantages of cellular design.

- Excess processing

Processes that take a long time to complete because there are more steps than absolutely necessary are an example of waste. Maybe the number of process steps has grown as a result of defects that have been accommodated over time and built into the process instead of being addressed at the root cause level. This may have led to multiple levels of inspection rather than looking at the entire process from a fresh perspective. Do it right the first time – destroy waste at the source.

(Ron Crabtree, 2010) also said in his book that the foundation of a successful business is having process pillars (Financial, Operations/Supply Chain, Quality, and Launch/Change) in place with robust processes supporting each one. When one pillar contains a weak process or a new requirement is introduced with no supporting processes, the pillar can become unstable, producing detrimental effects on other process pillars, compounding the issue. QPE (Quantify, Prioritize and Eliminate) is LSS methodology of making improvements and/or repairs to business processes through the DMAIC approach: establishing relevant metrics, disciplined collection of data, prioritizing the work to match capacity, and eliminating constraints through

proven tools and methodologies. Below are the explanations about QPE making improvements and/or repairs business process.

- QUANTIFY – Defining and Measuring the Process

QPE is an institutionalized process for the continuous elimination of constraints throughout the entire value chain. Constraints can be any problem or limitation on the free flow of the process; for example, defects, process steps, transactions, scans, moves, transfers, sign-offs, launch gates, inspection checkpoints, etc. Elimination or limitation of these constraints allows the process to move to completion much quicker because there are fewer steps, less stop/starts and less red tape. Setting up the methodology of defining and measuring each waste is important because of the need to have consensus between all team members, as well as to be detailed enough to allow the measurement to produce clearly defined targets for elimination.

Within the quantify stage, the basics of data collection are implemented, both in procedure and action. This can be at a work cell, product line or department level, depending on the necessity of a swift impact, with the eventual intention of implementing QPE company wide. During a QPE implementation, a team establishes performance metrics, then establishes the processes for data collection and compiles the first initial data. The important questions to ask within the team at this stage include: What is the process for data collection? When is the data collected? When is the data distributed? Who collects the data? Who reviews and distributes the data? Who gets the data? Who is accountable? Who is responsible? The acquisition of reliable data is extremely important during this stage and will likely include the negotiation of defect terms/types with the customer.

The trick here is to be tenacious concerning customer buy-in to the correctness and validity of the defects found. A daily review with the customer and all inspectors of the questionable defects will, in most cases, resolve any differences of opinion. Another best practice is to make sure all of the data recording sheets use the same terminology. This removes the “we said/they said” aspect of the QPE process. To complete this stage of QPE, confirm the data is flowing throughout the value chain, from customer defects all the way to supplier defects. Be sure not to focus solely on your internal operations, i.e., don’t let the collection of data stop at either the receiving or shipping docks, as this will become highly important during the next phase.

- PRIORITIZE – Analyze the Process

This phase is where data is given significance and containment changes are made. The team reviews and prioritizes the data, implements immediate containment activities between the different areas of inspection, and implements the initial corrective actions.

This phase needs to be implemented in an orderly fashion so you are not working on all of the cures for the all of the defects at the same time. By prioritizing defects into a Top 10 and Top 3 Pareto chart, you will bring the visual aspect of the QPE process to bear and make the direction you are heading readily understandable to anyone who cares to view the system. By attacking just the top three defects, you will most likely have an effect on close to 50% of your total system defects. Now that your containment initiatives are moving in the right direction, it is time to move on to the Elimination stage, which includes the institutionalizing, or permanent cultural change, of QPE.

- ELIMINATE – Improve and Control the Process

This phase includes implementation of permanent corrective actions, confirmation of the elimination through data, communication to all employees and proper timing to move to the next initiative. As you conducted the prioritization stage, you no doubt found easy fixes or stop gap measures for some of the Top 3 defects and quickly moved to implement corrective action.

Does your data reflect the elimination of these defects? In other words, have those defects been eliminated from reaching the customer through a corrective action that does not include inspecting them? If not, the potential for defects to reach the customer still exists. A good indicator of a permanent elimination of a specific defect is not finding the defect at any intermediary, final or in-process inspection locations. Not finding them anywhere in your process? Pat yourself on the back, and if necessary, request removal from the controlled shipping inspection process. Back up your request with the data. Remember: Additional inspection points and retraining operators are not permanent corrective actions, nor are they sustainable intermediate corrective actions. Make the changes to your process so the issue/defect/waste never comes back.

Just a few examples of corrective process changes include: initiating standardized work and process scrolling, witness marking, reducing the off-line rework (i.e., do it on the line, in-process), push-click-pull or tactile confirmations, the rollout of a sustainable SQA Program, addition of a production resource, initiating quality review of all rework, an electronic error-proofing system (including Andon), changing an assembly sequence, applying power to an assembly, revising the design to include poke-yoke fixes or improvements, and the addition of protective coverings on both A and/or B surfaces. With the implementation of these process changes, are your defects eliminated? Confirm it with data and communicate it to the customer and your employees by celebrating your success and commitment to QPE.

By quantifying, prioritizing and then eliminating constraints in your processes, your quality will increase as your costs go down, and customer satisfaction will skyrocket. Furthermore, communicating these successes throughout your organization will drive employee satisfaction and further improvement in your value chains (Ron Crabtree, 2010).

2.2.4. Six Sigma

Six Sigma based on the on the book “The Six Sigma Handbook” (Pyzdek, 2003) is a rigorous, focused and highly effective implementation of proven quality principles and techniques. Incorporating elements from the work of many quality pioneers, Six Sigma aims for virtually error free business performance. Sigma, σ, is a letter in the Greek alphabet used by statisticians to measure the variability in any process. A company’s performance is measured by the sigma level of their business processes. Traditionally companies accepted three or four sigma performance levels as the norm, despite the fact that these processes created between 6,200 and 67,000 problems per million opportunities. The Six Sigma standard of 3.4 problems per million opportunities is a response to the increasing expectations of customers and the increased complexity of modern products and processes. Six Sigma takes a handful of proven methods and trains a small cadre of in-house technical leaders, known as Six Sigma Black Belts, to a high level of proficiency in the application of these techniques. To be sure, some of the methods Black Belts use are highly advanced, including up-to-date computer technology. But the tools are applied within a simple

performance improvement model known as Define-Measure-Analyze-Improve-Control, or DMAIC.

Six Sigma is about helping the organization make more money by improving customer value and efficiency. To link this objective Six Sigma with quality requires a new definition of quality. For Six Sigma purposes define quality as the value added by a productive endeavor. Quality comes in two flavors*: potential quality* and *actual quality*. Potential quality is known maximum possible value added per unit of input. The difference between potential and actual quality is *waste*. Six Sigma focuses on improving quality by helping organizations produce products and services better, faster and cheaper. There is a direct correspondence between quality levels and "sigma levels" of performance. Six Sigma focuses on customer requirements, defect prevention, cycle time reduction, and cost savings. Thus, the benefits from Six Sigma go straight to the bottom line (Pyzdek, 2003).

Six Sigma is the application of the scientific method to the design and operation of management systems and business process which enabled employees to deliver the greatest value to customers and owners. The scientific method work as follows (Pyzdek, 2003):

1. Observes some important aspect of the marketplace or your business
2. Develops a tentative explanation, or hypothesis, consistent with your observations
3. Based on the hypothesis, make predictions.
4. Tests the predictions by conducting experiments or making further careful observations. Records the observations. Modifies the hypothesis based on the new facts. If variation exists, uses statistical tools to help separating signal from noise.
5. Repeats steps 3 and 4 until there are no discrepancies between the hypothesis and the results from experiments or observations.

The Six Sigma philosophy focuses the attention of everyone on the stakeholders for whom the enterprise exists. It is cause-and-effect mentality. Well-designed management systems and business process operated by happy employees cause customers and owners to be satisfied or delighted (Pyzdek, 2003).

Six Sigma activities focus on the few things that matter most to three key constituencies: customers, shareholders, and employees. The primary focus is on customers, but shareholder interests are not far behind. The requirements of these two groups are determined using scientific methods, of course. But the science of identifying what people want is not fully mature, so the data are supplemented with a great deal of personal contact at all levels of the organization. Employee requirements are also aggressively sought. Well-treated employees stay longer and do a better job (Pyzdek, 2003).

The traditional quality model of process capability differed from Six Sigma in two fundamental respects:

1. It was applied only to manufacturing processes, while Six Sigma is applied to all important business processes.
2. It stipulated that a "capable" process was one that had a process standard deviation of no more than one-sixth of the total allowable spread, where Six Sigma requires the process standard deviation be no more than one-twelfth of the total allowable spread.

These differences are far more profound than one might realize. By addressing all business processes Six Sigma not only treats manufacturing as part of a larger system, it removes the narrow, inward focus of the traditional approach. Customers care about more than just how well a product is manufactured. Price, service, financing terms, style, availability, frequency of updates and enhancements, technical support, and a host of other items are also important (Pyzdek, 2003).

The second point also has implications that are not obvious. Six Sigma is, basically, a process quality goal, where sigma is a statistical measure of variability in a process. The traditional quality paradigm defined a process as capability if the process's natural spread, plus and minus three sigma, was less than the engineering tolerance. Under the assumption of normality, this three sigma quality level translates to a process yield of 99.73%. Six Sigma requires that processes operate such that the nearest engineering requirement is at least Six Sigma from the process mean.

Six Sigma also applies to attribute data, such as counts of things gone wrong, this is accomplished by converting the Six Sigma requirement to equivalent conformance level, as illustrated in Figure 2.6

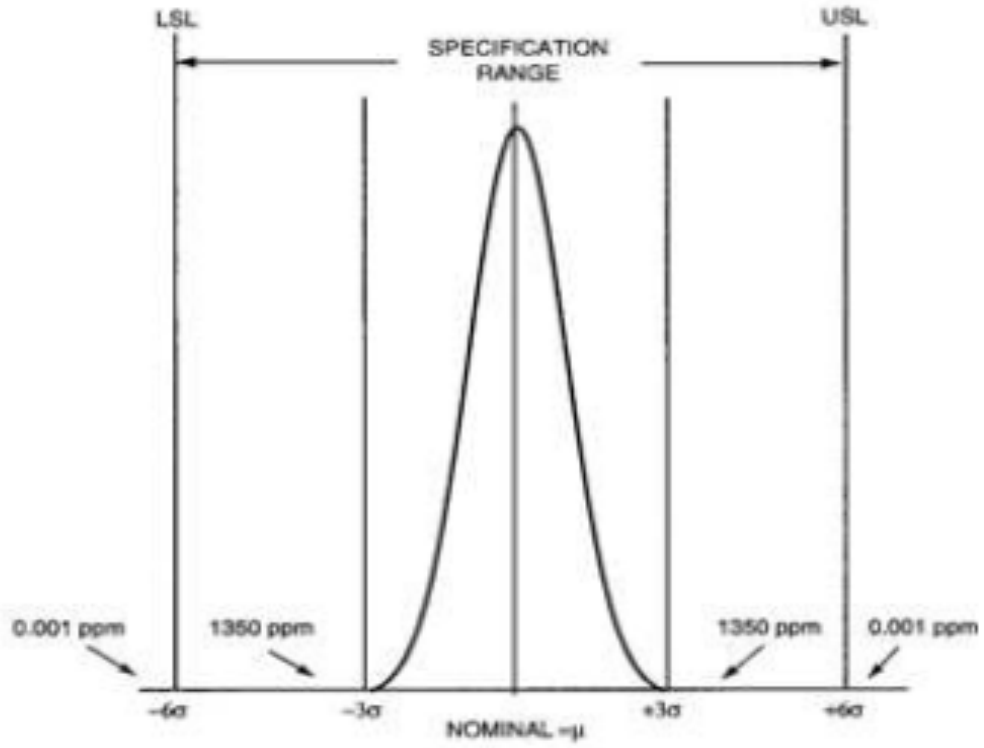


Figure 2.6 Sigma levels and equivalent conformance rates (Pyzdek, 2003)

In contrast to Six Sigma quality, the old three sigma quality standard of 99.73% translates to 2,700 PPM failures, even if we assume zero drift. For processes with a series of steps, the overall yield is the product of the yields of the different steps. If three sigma quality levels (99.97% yield) are obtained from every step in a ten step process, the quality level at the end of the process will contain 26,674 defects per million. Considering that the complexity of modern processes is usually far greater than ten steps, it is easy to see that Six Sigma quality isn't optional, it's required if the organization is to remain viable.

2.2.5. DMAIC Concept

Quality and process improvement occurs most effectively on a project-by-project basis. The tools of Six Sigma are most often applied within a simple performance improvement model known as Define-Measure-Analyze-Improve-Control, or DMAIC. DMAIC is a structured five-step problem-solving procedure that can be used to successfully complete projects by proceeding through and implementing solutions

that are designed to solve root causes of quality and process problems, and establish best practices to ensure that the solutions are permanent and can be replicated in other relevant business operations (Montgomery, 2009). DMAIC is summarized in Figure 2.7 DMAIC is used when a project's goal can be accomplished by improving an existing product, process, or service.

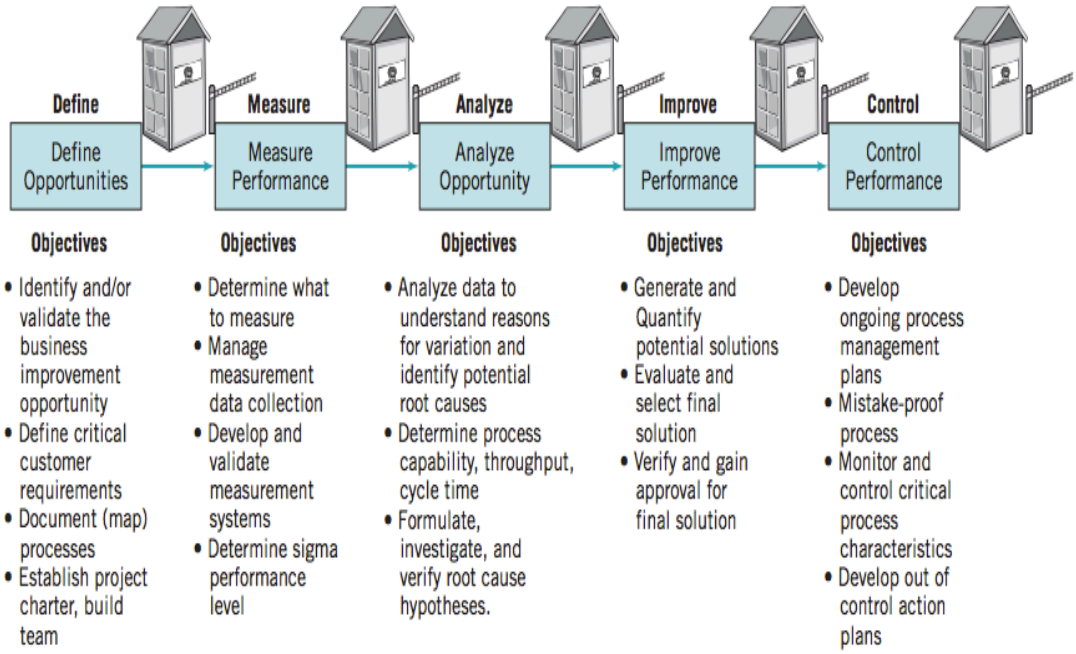


Figure 2.7 Overview of DMAIC (Montgomery, 2009)

Table 2.1 shows a partial listing of tools often found to be useful in a given stage of a project. There is considerable overlap in practice.

Table 2.1 Six Sigma tools commonly used in each phase of a project (Pyzdek, 2003)

Project Phase	Candidate Six Sigma Tools
Define	• Project charter • VOC tools (survey, focus group, letters, comment cards) • Process map • QFD, SIPOC • Benchmarking

Measure	• Measurement system analysis • Exploratory data analysis • Description statistics • Data mining • Run charts • Pareto analysis
Analyze	• Cause-and-effect diagram • Tree diagrams • Brainstorming • Process behavior charts (SPC) • Process maps • Design of Experiments • Enumerative statistics (hypothesis tests) • Inferential statistics (Xs and Ys) • FMEA • Simulation
Improve	• Force field Diagram • 7M tools • Project planning and management tools • Prototype and pilot studies
Control	• SPC • FMEA • ISO 900X • Change budget, bid models, cost estimating models • Reporting system

Another approach, used when the goal is the development of a new or radically redesigned product, process or service, is Define-Measure-Analyze-Design-Verify, or DMADV (Figure 2.8). DMADV is part of the design for Six Sigma (DFSS) toolkit.

D	*Define* the goals of the design activity. What is being designed? Why? Use QFD or the Analytic Hierarchical Process to assure that the goals are consistent with

	customer demands and enterprise strategy.
M	*Measure*. Determine Critical to Stakeholder metrics. Translate customer requirements into project goals.
A	*Analyze* the options available for meeting the goals. Determine the performance of similar best-in-class design
D	*Design* the new product, service or process. Use predictive models, simulation, prototypes, pilot runs, etc. to validate the design
V	*Verify* the design's effectiveness in the real world.

Figure 2.8 Overview of DMADV (Pyzdek, 2003)

Figure 2.9 below illustrates the relationship between DMAIC and DMADV.

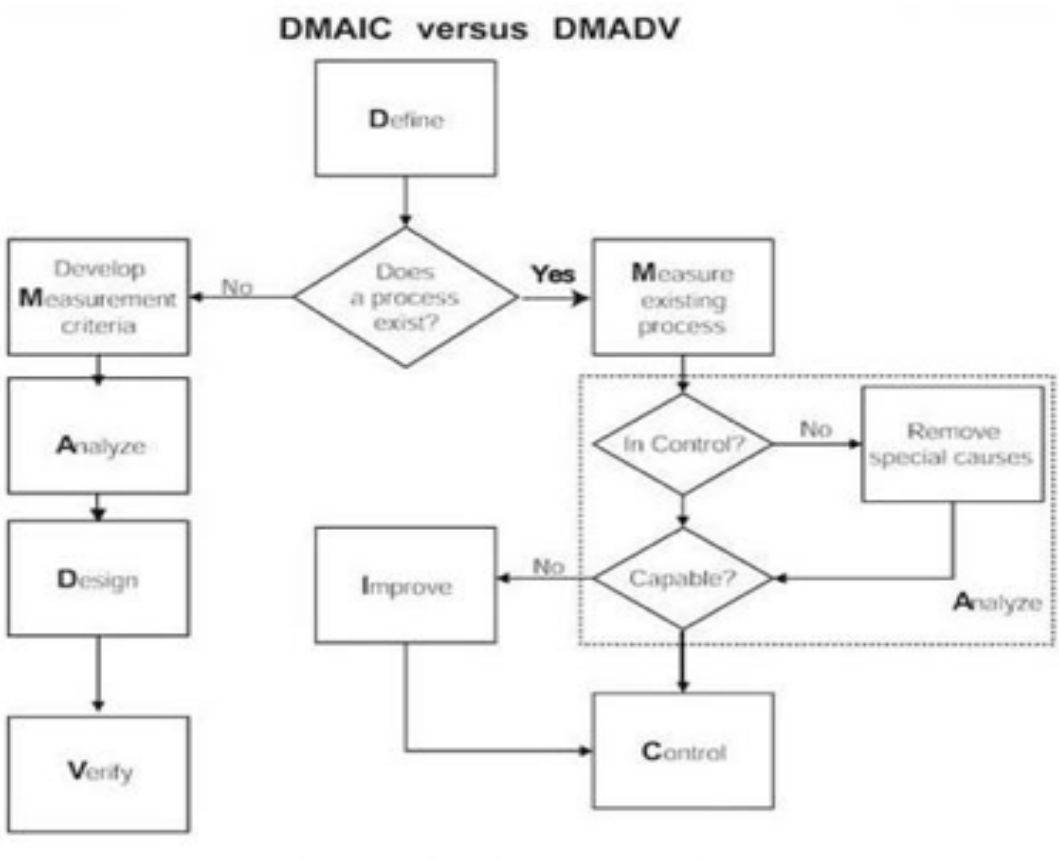


Figure 2.9 DMAIC and DMADV (Pyzdek, 2003)

2.2.6. Process Capability Analysis

Process capability analysis is a two-stage process that involves (Pyzdek, 2003):

1. Bringing a process into a state of statistical control for a reasonable period of time
2. Comparing the long-term process performance to management or engineering requirements.

Process capability analysis can be done with either attribute data or continuous data if and only if the process is in statistical control, and has been for a reasonable period of time. Application of process capability methods to processes that are not in statistical control results in unreliable estimates of process capability and should never be done. Process capability analysis is a vital part of an overall quality-improvement program. Among the major uses of data from a process capability analysis are the following (Montgomery, 2009):

1. Predicting how well the process will hold the tolerances
2. Assisting product developers/designers in selecting or modifying a process
3. Assisting in establishing an interval between sampling for process monitoring
4. Specifying performance requirements for new equipment
5. Selecting between competing suppliers and other aspects of supply chain management
6. Planning the sequence of production processes when there is an interactive effect of processes on tolerances
7. Reducing the variability in a process

The step-by-step approach to process capability analysis (Pyzdek, 2003):

1. Select a candidate for the study

This step should be institutionalized. A goal of any organization should be ongoing process improvement. However, because a company has only a limited resource base and cannot solve all problems simultaneously, it must set priorities for its efforts. The tools for this include Pareto analysis and fishbone diagrams

2. Define the process

It is all too easy to slip into the trap of solving the wrong problem. Once the candidate area has been selected in step 1, define the scope of the study. A process is a unique combination of machines, tools, methods, and personnel engaged in adding value by providing a product or service. Each element of the process should be identified at this stage. The input of many people may be required. There are likely to be a number of conflicting opinions about what the process actually involves.

3. Procure resources for the study

Process capability studies disrupt normal operations and require significant expenditures of both material and human resources. All of the usual project management techniques should be brought to bear. This includes planning, scheduling, and management status reporting.

4. Evaluate the measurement system

Evaluate the measurement system's ability to do the job. Factors that evaluate the measurement system such as:

- Scales of Measurement

In reality, measurement is problematic: the manager can never know the "true" value of the element being measured. The numbers provide information on a certain scale and they represent measurements of some unobservable variable of interest. Some measurements are richer than others, i.e., some measurements provide more information than other measurements. The information content of a number is dependent on the scale of measurement used. This scale determines the types of statistical analyses that can be properly employed in studying the numbers. Until one has determined the scale of measurement, one cannot know if a given method of analysis is valid.

The four measurement scales are: nominal, ordinal, interval, and ratio. The summary of the properties each scale is in Table 2.2

Table 2.2 Types of measurement scales and permissible statistics.

SCALE	DEFINITION	EXAMPLE	STATISTICS
Nominal	Only the presence/absence of an	go/no go;	percent;

	attribute: can only count items	success/fail; accept/reject	proportion; chi-square tests
Ordinal	Can say that one item has more or less of an attribute than another item; can order a set of items	Taste; attractiveness	rank-order correlation
Interval	Difference between any two successive points is equal; Often treated as a ratio scale even if assumption of equal intervals is incorrect; can add, subtract, order objects	Calendar time; temperature	Correlation; t-test; F-test; multiple regression
Ratio	True zero point indicates absence of an attribute; can add, subtract, multiply and divide	Elapsed time; distance; weight	t-test; F-test; correlations; multiple regression

- Reliability and Validity Data

Fundamentally, any item measure should meet two tests:

a. The item measures what it is intended to measure (i.e., it is valid)
b. A re-measurement would order individual responses in the same way (i.e., it is reliable).

- Overview Statistical Methods

There are two statistical methods that can be used. They are enumerative and analytic statistical methods. Deming defines that enumerative study is a study in which action will be taken on the universe and analytic study is a study in which action will be taken on a process to improve performance in the future.

The term ”universe” is defined in the usual way: the entire group of interest, e.g., people, material, units of product, which possess certain properties of interest. An

example of an enumerative study would be sampling an isolated lot to determine the quality of the lot.

In an analytic study the focus is on a *process* and how to improve it. The focus is the future. Thus, unlike enumerative studies which make inferences about the universe actually studied, analytic studies are interested in a universe which has yet to be produced. Table 2.3 compares analytic studies with enumerative studies.

Table 2.3 Important aspects of enumerative and analytic studies.

ITEM	ENUMERATIVE STUDY	ANALYTIC STUDY
Aim	Parameter estimation	Prediction
Focus	Universe	Process
Method of access	Counts, statistics	Models of the process (e.g., flowcharts, cause and effects, mathematical models)
Major source of uncertainty	Sampling variation	Extrapolation into the future
Uncertainty quantifiable?	Yes	No
Environment for the study	Static	Dynamic

Analytic study methods provide information for inductive thinking, rather than the largely deductive approach of enumerative statistics. Analytic methods are primarily graphical devices such as run charts, control charts, histograms, interrelationship digraphs, etc. Analytic statistics provide operational guidelines, rather than precise calculations of probability. Thus, such statements as “There is a 0.13% probability of a Type I error when acting on a point outside a three-sigma control limit” are false (the author admits to having made this error in the past). The future cannot be predicted with a known level of confidence. Instead, based on the knowledge obtained from every source, including analytic studies, one can state that has a certain degree of believe (e.g., high, low) that such and such will result from

such and such action on a process. Some appropriate analytic statistics question might be:

- Is the process central tendency stable over time?
- Is the process dispersion stable over time?
- Does the process distribution change over time?

If any of the above are answered “no” then what is the cause of instability? To help answer this question, ask “what is the nature of the variation as revealed by the patterns?” when plotted in time-sequence and stratified in various ways.

If none of the above are answered “no,” then, and only then, we can ask such questions as

- Is the process meeting the requirements?
- Can the process meet the requirements?
- Can the process be improved by re-centering it?
- How can we reduce variation in the process?

Another difference between the two types of studies is that enumerative statistics proceed from predetermined hypotheses while analytic studies try to help the analyst generate new hypotheses. In the past, this extremely worthwhile approach has been criticized by some statisticians as “fishing” or “rationalizing”. However, this author believes that using data to develop plausible explanations retrospectively is a perfectly legitimate way of creating new theories to be tested. To refuse to explore possibilities suggested by data is to take a very limited view of the scope of statistics in quality improvement and control.

- Principle of Statistical Process Control

A central concept in statistical process control (SPC) is that every measurable phenomenon is a statistical distribution. In other words, an observed set of data constitutes a sample of the effects of unknown common causes. It follows that, after we have done everything to eliminate special causes of variations, there will remain a certain amount of variability exhibiting the state of control.

There are three basic properties of a distribution: location, spread, and shape. The *location* refers to the typical value of the distribution, such as the *mean*. The *spread* of the distribution is the amount by which smaller values differ from larger ones. The standard deviation and variance are measures of distribution spread. The s*hape* of a distribution is its pattern-peakedness, symmetry, etc. A given phenomenon may have any one of number of distribution shapes, e.g., the distribution may be bell-shaped, rectangular-shaped, etc.

Without SPC, the bases for decisions regarding quality improvement are based on intuition, after-the-fact product inspection, or seat-of-the-pants ”data analysis”. SPC provides a scientific basis for decisions regarding process improvement.

A process control system is essentially a feedback system that links process outcomes with process inputs. There are four main elements involved, the process itself, information about the process, action taken on the process, and action taken on the output from the process. The way these elements fit together is shown in Figure 2.10 below.

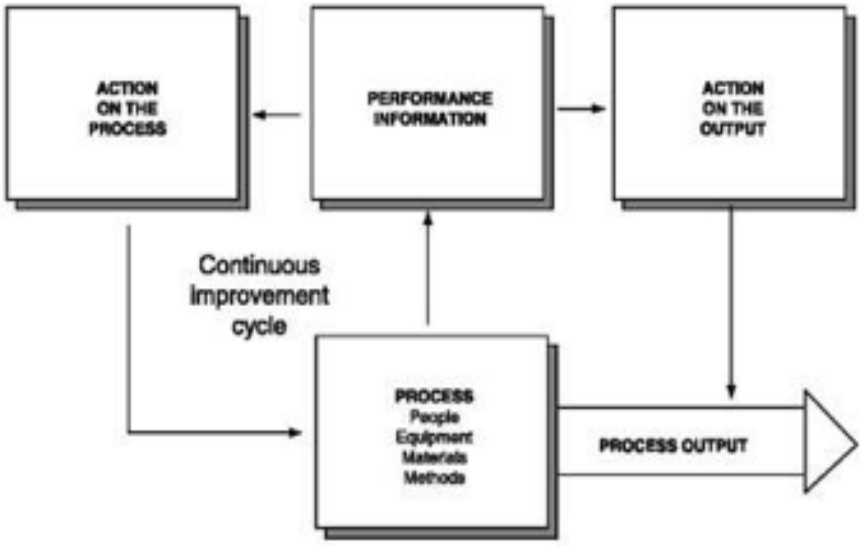


Figure 2.10 A process control system (Pyzdek, 2003)

By the process, we mean the whole combination of people, equipment, input materials, methods, and environment that work together to produce output. The performance information is obtained, in part, from evaluation of the process output. The output of a process includes more than product, it also includes information about

the operating state of the process such as temperature, cycle time, etc. Action taken on a *process* is future-oriented in the sense that it will affect output yet to come. Action on the output is past oriented because it involves detecting out-of-specification output that has already been produced.

There has been a tendency in the past to concentrate attention on the detection-oriented strategy of product inspection. With this approach, we wait until an output has been produced, then the output is inspected and either accepted or rejected. SPC takes you in a completely different direction: improvement in the future. A key concept is *the smaller the variation around the target, the better*. Thus, under this school of thought, it is not enough to merely meet the requirements; continuous improvement is called for even if the requirements are already being met. The concept of never-ending, continuous improvement is at the heart of SPC and Six Sigma.

5. Prepare a control plan

The purpose of the control plan is twofold: 1) isolate and control as many important variables as possible and, 2) provide a mechanism for tracking variables that cannot be completely controlled. The object of the capability analysis is to determine what the process can do if it is operated the way it is designed to be operated. This means that such obvious sources of potential variation as operators and vendors will be controlled while the study is conducted. In other words, a single well-trained operator will be used and the material will be from a single vendor.

There are usually some variables that are important, but that are not controllable. One example is the ambient environment, such as temperature, barometric, pressure, or humidity. Certain process variables may degrade as part of the normal operation: for example, tools wear and chemical are used. These variables should still be tracked using log sheets and similar tools.

6. Select a method for the analysis

The SPC method will depend on the decisions made up to this point. If the performance measure is an attribute, one of the attribute charts will be used. Variables chart will be used for process performance measures assessed on a continuous scale. Also considered will be the skill level of the personnel involved, need for sensitivity, and other resources required to collects, record, and analyze data.

7. Gather and analyze the data

Use one of the control charts plus common sense. It is usually advisable to have at least two people go over the data analysis to catch inadvertent errors in entering data or performing the analysis. There are two types control charts that are control chart method for attribute data and variables data.

- Control Chart Method: Attributes Data

a. Collect samples from 25 or more subgroups of consecutively produced units. If defect very small, we should choose n sufficiently large so that we have a high probability of finding at least one nonconforming unit in the sample. "Using the Poisson approximation to the binomial, we find from the cumulative Poisson table that $\lambda = np$ must exceed 3.00"(Montgomery, 2009).

b. Plot the results on appropriate control chart. If all groups are in statistical control, go to step c. Otherwise identify the special cause of variation and take action to eliminate it. Note that a special cause might be beneficial. Beneficial activities can be "eliminated" as special causes by doing them all of the time. A special cause is "special" only because it comes and goes, not because its impact is either good of bad. Table 2.4 below shown control chart formula for attribute data (p, np, c, and u control charts).

Table 2.4 Control Chart Formulas in Attribute Data (Montgomery, 2009), (Pyzdek, 2003)

	p (fraction)	np (number of nonconforming)	c (count of nonconformances)	u (count of nonconformances/ unit)
CL	$\overline{p}$	$n\overline{p}$	$\overline{c}$	$\overline{u}$
UCL	$\overline{p} + 3\sqrt{\frac{\overline{p}(1-\overline{p})}{n}}$ or 1 if UCL is	$n\overline{p} + 3\sqrt{n\overline{p}(1-\overline{p})}$ or n if UCL is	$\overline{c} + 3\sqrt{\overline{c}}$	$\overline{u} + 3\sqrt{\frac{\overline{u}}{n}}$

	greater than 1	greater than n		
LCL	$\overline{p} - 3\sqrt{\frac{\overline{p}(1-\overline{p})}{n}}$ or 0 if LCL is negative	$n\overline{p} - 3\sqrt{n\overline{p}(1-\overline{p})}$ or 0 if LCL is negative	$\overline{c} - 3\sqrt{\overline{c}}$ or 0 if LCL is negative	$\overline{u} - 3\sqrt{\frac{\overline{u}}{n}}$ or 0 if LCL is negative
Notes	If n varies, use $\overline{n}$ or individual n_i	n must be a constant	N must be a constant	If n varies, use $\overline{n}$ or individual n_i

c. Using the control limits from the previous step (called operation control limits), put the control chart to use for a period of time. Once you are satisfied that sufficient time has passed for most special causes to have been identified and eliminated, as verified by the control charts, go to the step d.

d. The process capability is estimated as the control chart *centerline.* The centerline on attribute charts is the long-term expected quality level of the process, e.g., the average proportion defective. This is the level created by the common cause of variation.

If the process capability doesn't meet management requirements, take immediate action to modify the process for the better. "Problem solving" (e.g., studying each defective) won't help, and it may result in tampering. Whether it meets requirements or not, always be on the lookout for possible process improvements. The control charts will provide verification of improvement.

- Control Chart Method: Variables Data

a. Collect samples from 25 or more subgroups of consecutively produced units.

b. Plot the results on the appropriate control chart (e.g., $\overline{X}$ and R charts). If all groups are in statistical control, go to the step c. Otherwise identify the special cause of variation and take action to eliminate it.

c. Using the control limits from the previous step (called operation control limits), put the control chart to use for a period of time. Once you are satisfied that sufficient time has passed for most special causes to have been identified and eliminated, as verified by the control charts, estimate process capability as described below.

The process capability is estimated from the process average and standard deviation, where the standard deviation is computed based on the average range of average standard deviation. When statistical control has been achieved, the capability is the level created by the common causes of process variation.

8. Track down and remove special causes

A special cause of variation may obvious, or it may take months of investigation to find it. The effect of the special cause may be good or bad. Removing a special cause that has a bad effect usually involves eliminating the cause itself. For example, if poorly trained operators are causing variability the special cause is the training system (not the operator) and it is eliminated by developing an improved training system or a process that requires less training. However, the "removal" of a beneficial special cause may actually involve incorporating the special cause into the normal operating procedure. For example, if it is discovered that materials with a particular chemistry produce better product the special cause is the newly discovered material and it can be made a common cause simply by changing the specification to assure that the new chemistry is always used.

9. Estimate the process capability

One point cannot be overemphasized: *the process capability cannot be estimated until a state of statistical control has been achieved!* After the numerical estimate of process capability has been arrived at, it must be compared to management's goals for the process, or it can be used as an input into economic models.

10. Establish a plan for continuous process improvement

Once a stable process state has been attained, steps should be taken to maintain it and improve upon it. SPC is just one means of doing this. Far more important than the

particular approach taken is a company environment that makes continuous improvement a normal part of the daily routine of everyone.