Research Methodology

“In the annals of innovation, new ideas are only part of the equation. Execution is just as important.”

Walter Isaacson

This research attempts to integrate two schools of thought, the strategy of 6σ and the theory of multilevel modeling to quantify the quality of an academic institution. This chapter illustrates the methods and arguments for the use of the same. The methodology adopted here is primarily on the concepts of 6σ theory concurrent to the standard practices of research. Re-iterating the objectives of research, they are as follows:

- To gain an understanding on how the Six-Sigma strategy can be integrated (in partial) to the quality analysis of the Academia
- To identify a set of key indicators and their metrics to define quality in Academia
- To generate the Quality index based on mathematical model using key indicators

3.1 6σ as a methodology

Primarily the six sigma philosophy is a customer driven & data oriented process. With a proven effect in the manufacturing sector, the philosophy has made its way significantly into the service sector as well.

The philosophy looks at

1. Definition of Quality by Customer
2. Identification of variables that match the definitions
3. Measuring the variables in the process
4. Analyzing the current process to match with the customer expectations (sigma level of the process)
5. Improving the process
6. Locking the improvements to control the process

(Pande, Neuman, & Cavanagh, 2008), (Jeroen & Bisgaard, 2007)
(Sigma, Six-Sigma Pre-course Reading material, Version 6.0, 2010)
This chapter envisages the Define, Measure, Analyze and Improve stages of the DMAIC strategy while trying to concur to the concepts of the customary research methodology.

![Diagram of DMAIC methodology]

**Figure 3.1: The 6-Sigma Road Map**  
(Coletta, 2012); (Pande, Neuman, & Cavanagh, 2008)

Parallel to this and with the standard procedures of scientific research, this study was conducted in the following stages:

- **Stage 1 – Literature review of six sigma and Quality of Academics**
- **Stage 2 – Survey to identify determinants of quality in Academics**
- **Stage 3 – Instrument development and survey within institutions**
- **Stage 4 – Analysis of data**
- **Stage 5 – Cross comparison of the survey results with the priority indices and the operating sigma levels of the quality determinants.**

### 3.2 Stage 1 – Literature review of 6σ and Quality of Academics

The initial step to gain an understanding of the viability of 6σ as a strategy for quality analysis in academic institutions, articles were examined in two directions *viz-a-viz* 6-sigma and Quality in Academics. Text books, journal articles, conference
Two textbooks The Six Sigma Way (Pande, Neuman, & Cavanagh, 2008) and Demystifying Six Sigma (Larson, 2003), Two magazines, The TQM magazine, Six Sigma Insight and the websites www.isixsigma.com and www.benchmarksixsigma.com largely contributed to the comprehension of Six-sigma as a strategy, its growth, current practices, its scope and limitations. Directed readings in the areas of Quality of academics were done from two specific points of view. One, the processes in practice by various accreditation agencies across the globe essentially to gather an understanding of what processes are considered important by the external audit agencies of the Academia { (EDU, 2007), (NCIE, 2003), (NAAC, 2012), (MOHESR, 2008), (CMA, 2007) and more}. Secondly readings were directed to research findings in the areas of Academic Quality. The study necessitates the need to understand the various dimensions of Quality assessment undertaken by Academic institutions. These readings were also to identify the existing parameters of quality for an academic institution.

A third dimension to this search was a combination of six-sigma and Academia. As is the objective of this study, the practices of quality measurement by Academic institutions were studied from the six-sigma point of view. Several researchers and practitioners of six-sigma propagated the use of six-sigma in the service industry and thereby readings to establish similarities between the six-sigma strategy and the current practices of quality measurement were harped upon. Few articles have been published on studies that use six-sigma as a strategy in Academic institutions (Antony, 2004) (Breyfogle F. W., 2003).

A fourth facet to the study is the use of multilevel models in estimating parameters of the model in place. Initial observations about the structure of the data showed that it was hierarchical, a situation where the observations making up a data set are not all equivalent. The observations are heterogeneous, i.e. they occur in groups such that within the group they exhibit less variability than exists for observations coming from different groups. The purpose of this review is to understand the model, its significant parameters and the use of multilevel modeling in social science studies and behavioral studies. The underlying emphasis of the study basically is to formulate the findings of this quality oriented study into a multi-level model. The sources definitely are exhaustive and far reaching. Hence the study and reading will be limited to the preferences and perceptions with regard to contribution of the literature to the area of study.

The start was with an exhaustive search of all literature related Multilevel modeling, including textbooks, research articles, reports, conference proceedings and (other) electronic sources to name a few. Text books ‘Generalized Linear
Models by Jeff Gill, Multilevel modeling by Luke and Multilevel Statistical modeling by Goldstein (Goldstein, 1992) greatly contributed to this review. A number of available articles were categorized based on information about the theory of MLM and advanced level research in theory or applying MLM to social data. The basic concepts and the definitions with regard to multilevel models were sought from the writing of several researchers and authors (Gogard, 2003), (Hox, 1995), (Raudenbush & Bryk, 2004), (Goldstein, 1992), (Snijders & Bosker, 1999).

The next level was to seek advanced theoretical research done in MLM. Abstracts and full texts were browsed upon from a range of online resources which included websites of Centre for Multi modeling, Bristol; Trans.data archive-MLwiN; Wiley.com; Sciencedirect.com; Economic and Social Research Council and Wikipedia to name a few. More often than not the articles were mostly retrieved from Proquest. Most of the sites did have fully published articles, while a few showed abstracts from which one could choose to draw conclusions if not for a price. The prime topics of interest for some or all of the analysts have been that of Correlation & Cluster effects, Erroneous assumptions about residuals and most importantly simulation methods to estimate fixed and random effects of MLM.

The third deliberation and most importantly was the application of MLM in research on social issues. It turned out that MLM was very extensively used in areas of health and hospital related studies. (Online Sources: ESRC, SSRN, Sciencedirect.com, MLwiN, LEMMA, SAGE, etc.) Other areas of application included a mixture of Behavioral studies that included "Effects of family on education" (Dearing, McCartney, Weiss, Kreider, & Simpkins, 2004), "Educational and Social Research" (Goldstein H., 1987), “Children’s schooling and social competence” (Clements, Reynolds, & Hickey, 2004), etc. The list is quiet extensive as far as the application of MLM is concerned with a major share of work being done in Health related and associated areas. A thorough reading on a selected few articles helped analyze how MLM was used to discover certain undermined aspects of the population as well as it also brought about the falsely assumed facets.

Text books, journal articles, conference proceedings, news reports documents, Magazines, blogs and websites encompassed the sources for the readings. The bibliography comprised of 154 citations/references that were narrowed down for use in the literature review.

3.3 Stage 2 - Identifying Determinants of Quality
Customer requirement is the key to any Quality study. It was imperative to first begin the study with a clear definition of customer satisfaction determinants.
The inherent processes in academic institutions were identified through Literature reviews. Searches in the literature were to realize the existing practices of quality assurance. As is apparent, these practices will inspect various aspects of an academic institution. A systematic reading of such, helped in assimilating the primary information regarding the various facets that contribute to the quality of an Academic Institution.

This was furthered by experiences survey with Members of the Academic fraternity approached (mostly through informal meetings) for discussions about the governing processes in an Academic institution. While preliminary readings proved that the quality of an institution was represented by numerous variables, discussions helped filter and classify the processes and their sub processes as well.

3.3.1. Gauging the determinants in the current market

Considering the ever-changing dynamics of the education-market, the next step was to correctly identify (and to reiterate or counter the literature findings) from the existing clients and stake holders, their views on the pre-requisites for quality of education. Such a triangulated collection of data helped in prioritizing the variables critical to the quality of an academic institution in general (Cohen & Manion, 2000). The study was initialized through dialogues with individuals (on a broader beginning) to gather generic information. This was followed by both casual dialogues and focused discussions. Eventually a questionnaire with the fundamental question was distributed and responses gathered. An open question as to what comes to a person’s mind when one says ‘quality of an academic institution’ helped amass an inventory of parameters.

The target population at this phase of study comprised of all individuals who are necessarily graduates who have pursued their studies in a university or institutions of higher education. The convenience sampling technique was adhered to select the sample. Mails were sent out to individuals from an existing mailing list and individuals were approached personally for their opinion. 398 (of 500) answered the question “What in their opinion were the top 5 parameters critical to the quality of an academic institution?” along with a host of other questions. Alternatively when self-administered, the question was also posed as “What are the 5 factors that come instantly to your mind when one speaks of quality of an academic institution?”. Discussions with members at different levels of the work-force ranging from Academicians to Physicians, Engineers, Lawyers, working professionals from various sectors, Parents and students as well, contributed in an extensive way. Some participants insisted on suggesting more than five parameters maintaining that these variables are all bricks of the same wall, even one missing or slightly
lesser in quality can make the wall weak. Individuals from different schools of study (Management / Art / Engineering / Medical Sciences etc...) mentioned factors prioritized accordingly, however factors generic to an institution / university was sought for the purpose of this paper. The Define stage in the DMAIC cycle is concurrent to the goal of identifying customer issues and requirements and defining the internal processes that address them (CIMBA, 2001). The chief objectives being to identify/ validate the opportunity develop the business processes and translate the Voice of the Customer (VOC) to Critical Customer Requirements. A high level process map is the key deliverable of this phase. A fish bone diagram was constructed based on the findings of the study also highlighting the various (common) processes in an academic institution.

3.4 Stage 3: Instrument development and survey within institutions

The main activities in this phase were to identify the Input process and output indicators, develop a measurement plan and determine the current sigma performance. The key deliverable at this phase is a reliable assessment of the current performance. Initial observations about the structure of the data showed that it was hierarchical, a situation where the observations making up a data set are not all equivalent. The observations are heterogeneous, i.e. they occur in groups such that within the group they exhibit less variability than exists for observations coming from different groups.

The processes and thereby the variables identified were then categorized into two broadly based levels in the institution.

1. Processes within and specific to the department
2. Processes governing the department and general to the university or the institution as a whole.

The six sigma strategy is essentially a process that facilitates an internal audit by allowing the organization to introspect on the state-of-affairs within its process. Unlike that of a manufacturing unit, processes in the Academic institutions are subject to the most important aspect of intangibility that is inherent of service processes. The variables identified in the first level of inventory are attitude based and of qualitative nature.
Quantification of the qualitative variables used in this study was done using ratings. A five point Likert's scale rating was used for measuring the variables, 5 being excellent and 1 being least satisfactory. Characterization of a defect is a matter of debate in the case of services. The six-sigma philosophy is primarily to identify the level of non-conformities in the process output. Considering the utility of the study, the definition of non-conformity is the prerogative of the institution that uses this model. For example, a rating of 2 and less was suggested as non-conformity.

A new word to indicate the same is coined in lieu of the same.

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**Lackademic (Noun)**: A low rating given to an attribute indicating a lacuna in the quality of academia

**LPMO**: Lackademics per million opportunities

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A count of the same is used to estimate the sigma level of the process.

The choice of institution was subject to the institution’s acceptance to participate in the study. Resistance to the same was foreseen and experienced. This (in my opinion) is due to the fact this is a quality study based on the feedback of students and if not taken in the right outlook may be a cause of apprehension. For institutions that obliged to participate in the study, responses are gathered from all senior grade students. Two institutions participated in the study. Institution 1- The Manipal University, Dubai Campus, Dubai, UAE and Institution 2- Bharathiya Vidyabhavan’s Vivekananda College (affiliated to the Osmania University) Hyderabad, India. A Complete census was conducted with all senior grade students in the sample; 445 students from the 6 departments of Institution 1 and 458 students from the 7 departments at Institution 2 were a part of the two independently conducted surveys. Data is collected at two levels, Students within the department and Departments across the University (Institution).

The instrument used is a questionnaire which was first pilot tested and then furthered into a full-fledged survey. The questionnaires were self-administered to the respondents. Clarifications regarding the definitions of the terms used in the questionnaire were carefully clarified with care to avoid/ minimize any investigator bias.
As is the objective of the research project, responses were based on the student ratings given to the services factors representative of academic quality.

Questionnaires requesting respondents to rate the attributes significant of academic quality were self-administered to the students. The questionnaire consisted of two constructs besides questions on year of study, gender and discipline of study and grade-point average in the last examination. The items in the first construct related to generic parameters namely Value for money, Institution infrastructure, Global recognition of the institution, Evaluation system, Support facilities and Library. A cumulative of the ratings (Both weighted and absolute) is the response variable. The second construct was department related with Faculty, Industry Interface, Research Opportunities, Placement facilities and Department infrastructure as the operating variables. Data is obtained on the basis of ratings (given by the students). The student level observations were the ratings and details collected at the student level. Observations were made at both student level and department level. At the department level the five variables were (a) Average number of research publications by faculty, (b) Placement %, (c) Overall Pass %, (d) Number of workshops/guest talks conducted, (e) Number of awards/ recognitions by the department. These variables used in the study were weighted according to the priority stated in a prior research by the authors (Nair & Biju, 2010). Assuming a 2-level model here, multilevel models were worked out for each of the two institutions. The response variable $Y$ is a sum total of 6 variables generic to the institution. The student level explanatory variables are first assigned weights based on the priority assigned to them. With the topmost cited attribute at rank 1, ranks are assigned to attributes that are global to the institution/university and also specific to the school/discipline of study.

3.5 Stage 4 – Data Analysis

Analysis of data is done in two directions

- Identifying the Sigma level of each process
- Using the data to generate a multilevel model
3.5.1 Sigma Analysis: (Manufacturing Processes)
The performance of the processes can be compared throughout an entire organization by determining the sigma levels of the processes. Determining the sigma levels is independent of the process, as it calculates only opportunities and defects. Different processes may differ in number of opportunities for making mistakes and different number of units produced, however by comparing the DPMO of these processes we can make out which process is performing better.

The sigma measure may be used as an indicator to the present operating process levels. This can be viewed as starting point to an investigation. There are various sigma levels of the processes. A sigma level of the process determines the accuracy and quality of the process. By knowing the sigma level of the process we can make out how the process is performing for eg. How many defects are occurring during the process? Higher the sigma number of the process, higher will be the accuracy and quality of it. The calculation is based on the number of the defects occurring per million of opportunities.

**DPMO is Defects per million opportunities**

\[
DPMO = \frac{\text{Number of defects}}{\text{Number of units observed}} \times 1000000
\]

**Equation 3.1**

The relationship between the sigma levels and DPMO suggests the efficiency of the process. Higher sigma level means a lower value for the DPMO and increased levels of process efficiency. Alternatively, lower sigma level indicates high value for the DPMO and decreased levels of process efficiency. Therefore a process should aim to achieve the higher Sigma Levels.

Relationship between Sigma Levels and DPMO is as follows:

- One sigma = 690,000 DPMO = 31% efficiency
- Two sigma = 308,000 DPMO = 69.2% efficiency
- Three sigma = 66,800 DPMO = 93.32% efficiency
- Four sigma = 6,210 DPMO = 99.379% efficiency
- Five sigma = 230 DPMO = 99.977% efficiency
- Six sigma = 3.4 DPMO = 99.9997% efficiency
In the study of this sort, where the ratings are considered as measures of quality, the lackademic count per variable is counted and the LPMO for that process is measured.

\[
LPMO = \frac{\text{Number of Lackademics}}{\text{Number of units observed}} \times 1000000
\]

Equation 3.2

3.5.2 Fitting a Multilevel model
As was observed (in the Define stage) in educational research, data often have a hierarchical structure, with students grouped within departments, which have qualities that influence the response variable. Students form the first level of units and the departments to which they belong to are the second level units.

The survey conducted in the define phase helped prioritize the variables based on the number of respondents who included them in their priority list of quality indicators. Based on this result, a priority index is computed for the variables that were included in the survey questionnaire.

Consider the model with K attributes; then the calculation of weights is done using a choice from the following (Buede):

- **Rank Centroid Formula**

  \[
  wt_i = \left( \frac{1}{K} \right) \sum_{j=i}^{K} \left( \frac{1}{r_j} \right); \quad \text{Equation 3.3}
  \]

- **Rank Reciprocal**

  \[
  wt_i = \frac{1 / r_i}{\sum_{j=1}^{K} (1 / r_j)} \quad \text{Equation 3.4}
  \]
• **Rank Sum**

\[
wt_i = \frac{K - r_i + I}{\sum_{j=1}^{K} [K - r_j + I]}
\]

_EQUATION 3.5_

• **Normalized averages**

\[
wt_i = \frac{r_j}{\sum r_j}
\]

_EQUATION 3.6_

The primary descriptions of the survey conducted in the measure stage are done using bar graphical representations, averages and their respective standard deviations.

3.5.2.1 **Model Development**

SPSS version 15.0.1 was used for the analysis _SPSS for windows, Rel. 15.0.1, 22 November 2006, SPSS Inc., Chicago, IL, USA_

In this study, \( x_{kij} \) denotes the quality rating by the \( i \)th student in the \( j \)th group for the \( k \)th attribute. \( x_{kij} \) takes values 1 to 5 (Poor rating to Excellent rating). With the weight assigned to it, the value is transformed to

\[
x_{kij}^* = x_{kij} \times wt_k
\]

_EQUATION 3.7_

The estimation is carried out using \( x_{kij}^* \) as the explanatory variables, analogous to the usual procedure of multilevel modeling. The response variable \( Y_{ij} \) which denotes the quality index is computed in two ways

**A:** The response variable as the absolute sum of un-weighted ratings of 6 generic attributes

**B:** The response variable is the weighted sum of the 6 generic attributes.
If all of the generic attributes are rated at 1 then the response variable will assume a minimum value 6. If all of the generic attributes are rated at 5 then the response variable will assume a maximum of 30. When absolute values are used the response variable is in the range [6, 30]. Alternatively when weighted according to the priority index, the response variable lies in the interval [1, 5]. The model is developed as follows:

Step 1: The baseline model or the unconditional means model is first developed.

Step 2: The intra class correlation coefficient is computed to examine how much of the variation in the response variable is due to the within and between department factors.

Step 3: The level 1 model is then developed for the response variable as a function of the six student level variables of the second construct.

At the student level, the model based on P-explanatory variables is

\[ Y_{ij} = \beta_0 + \sum_{p=1}^{p} \beta_p X_{pj} + \epsilon_{ij} \] \hspace{1cm} \text{Equation 3.8}

Step 4: A two level model based on P-explanatory variables (X) at level 1 and Q variables (Z) at level 2 based on J groups is given by

\[ Y_{ij} = \beta_{0j} + \sum_{p=1}^{p} \beta_{pj} X_{p_{ij}} + \epsilon_{ij} \]

\[ \beta_{0j} = \beta_0 + \gamma_{0j} Z_j + u_{0j} \] \hspace{1cm} \text{Equation 3.9}

\[ \beta_{pj} = \beta_p + \gamma_{pj} Z_j + u_{pj}; \ j = 1,2,...,J \]

To make inferences based on the variables at the student level (the lowest level of hierarchy) a simple regression model would suffice. This Random intercept model accommodates the correlation of outcomes within the departments, thereby reducing the bias in error estimates. Also variables measured at different levels of hierarchy helps examine how regression relationships vary across clusters (Austin & Goel, 2001); (Jin, Nie, & Xiao, 2008) (Bottai & Salvati, 2006)
To study the student level characteristics and to verify the variability of models across departments, the random-intercept and random-slope model is apt. The Final model used in this study uses the following variables (Table 3) at the specified levels.

Explanatory variables are then introduced one at a time into the model. The choice of predictors is vital to any design, more so in multilevel modeling as variables come from more than one level. Further interaction between predictors too is of significance at each instant. (Little, Linderberger, & Nesselroade, 1999). Inclusion of variables into the model is based on the descending order of significant correlation between the response variable and the predictor variable.

<table>
<thead>
<tr>
<th>Table 3.1: Table showing variable description</th>
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<tbody>
<tr>
<td>Variable</td>
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<tr>
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</tr>
<tr>
<td>Y</td>
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<tr>
<td>Student level variables</td>
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<tr>
<td>Department level variables</td>
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The model was then furthered as follows

- Introduce student level variables beginning with those with highest correlation with the dependent variable.
- Retain the variable if the parameter estimate is significant (p<0.05)
- Retain the effects as fixed and proceed to build a model with only level 1 variables and fixed effects
- At the end of each new introduction, the difference between the -2LL (-2 log likelihood) is used to conclude about the significant difference in goodness of fit of the current model when compared to the previous model. The difference (Δ) between the -2LL values of the two models follow the Chi-square distribution with the degrees of freedom equal to that of the difference between the number of parameters estimated in the two models.

\[
\chi^2_{cal} = \Delta(-2LL_{mod\,el_{B_{n+1}}} , -2LL_{mod\,el_{A_n}} ) \sim \chi^2_k
\]

**Equation 3.10**

- Improve the variables, one at a time to random effects to complete the growth model in which all the explanatory variables are with random effects (Based on their significance)
- Identify the best model, based on the chi-square test for goodness of fit to proceed to the introduction of level 2 variables.
- Introducing level 2 (Department level) variables, the predictors may be used to explain intercept variability, Slope variability or both! The equations are as in equation 5 through 16.
3.6 Stage 5: The stated priority v/s derived index matrix

It is of value in a competitive setting to understand the possible toggle between the stated priority of influencing variables and their actual derived effect in a real time situation (Yang & Peterson, 2004). Categorizing them (Matzler, Bailom, Hinterhuber, Renzl, & Pichler, 2004) in a matrix as shown below allows decision makers at the institutions to control variables that show both high priority and effect on the response variable while laying focus on variables that show (statistically significant) effect and will be of value addition in spite of a stated low priority.

<table>
<thead>
<tr>
<th>Derived Effect (Based on regression coefficient)</th>
<th>High</th>
<th>Variables of relevance Value added benefits (Opportunity areas)</th>
<th>Key selling points Primary areas to maintain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Low</td>
<td>Secondary opportunity areas</td>
<td>Essential support Points / Potential Differentiators</td>
</tr>
<tr>
<td>(Lieberman)</td>
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</table>

**Figure 3.2: Derived Effect v/s Stated Priority**

In this study the stated importance is based on the number of respondents who have stated the variable as important and of high importance. The derived effect is based on the regression coefficients as computed for the multilevel model in place. The key objective in the Improve phase of the DMAIC cycle is to identify, evaluate, and select the right improvement solutions. This research does not delve completely into the implementation in the Improve phase owing to the limitation of the study. Essentially this phase requires generation of solution ideas, determination of benefits while screening the alternatives between solutions and requiring high level planning. A process mapping is what is done as a part of the study to allow the institution (Client) to determine the status quo.