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Tools, Techniques and Utilities used in Doctoral & Post-Doctoral Research

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Abstract

This paper explains different Tools, Techniques and Utilities that are used in Doctoral & Post-Doctoral Research in different area. In the realm of academic pursuit, doctoral and post-doctoral research stand as pinnacle achievements, demanding rigorous inquiry, innovation, and precision. This abstract provides an overview of the diverse array of tools, techniques, and utilities that scholars harness to navigate the intricacies of their research journeys. In the research to use these tools, techniques, and utilities an IT industry is considered. The various techniques, methodologies, and tools used in these papers are to assess whether software products meet the specified requirements, function correctly, and provide a positive user experience.

Keywords – Pareto chart, Regression analysis, Goal Question Matrix (GQM), Goal Decomposition Method (GDM), Balanced Score Card (BSC), Fishbone

Introduction

In the dynamic landscape of academia, where knowledge creation and dissemination are paramount, the pursuit of doctoral and post-doctoral research emerges as a pinnacle endeavor. The trajectory of these advanced research pursuits is marked by intellectual exploration, meticulous investigation, and the quest for innovative solutions to complex problems. At the heart of this scholarly expedition lies an arsenal of tools, techniques, and utilities that equip researchers with the means to unravel intricate challenges, analyze multifaceted data, and communicate their discoveries effectively.

In this digital age, the toolkit available to researchers has expanded exponentially, offering a diverse array of instruments tailored to the distinct demands of their fields of study. These tools are more than mere conveniences; they have evolved into indispensable companions, empowering scholars to navigate the complexities of data management, statistical analysis, collaboration, and beyond. The interplay of these tools, techniques, and utilities orchestrates a symphony of inquiry, enabling researchers to delve deeper, reach further, and contribute meaningfully to the tapestry of human knowledge.

This paper delves into the multifaceted landscape of tools, techniques, and utilities that are integral to the journey of doctoral and post-doctoral research. Through an exploration of these elements, we aim to illuminate the pathways through which researchers harness technology and innovation to push the boundaries of academic exploration. By examining the diverse roles these tools play in the research process, we seek to underscore their significance as enablers of scholarly achievement, efficiency, and impact.

As we embark on this journey through the realm of research tools and techniques, it becomes evident that they are not mere adjuncts to the scholarly pursuit; they are the very scaffolding that supports the construction of new knowledge. From the inception of a research idea to the dissemination of findings, the

integration of these tools weaves a narrative of scholarly endeavor, shaping the trajectory of inquiry and underscoring the ever-evolving nature of academic exploration.

The tools used during our research are described in the next sections.

Different tools

1. Pareto Chart

Brief Description of the Tool

A Pareto chart is a type of chart with both a bar and a line chart, where the bars reflect individual values in descending order and a cumulative total line. The graph is named after the Pareto principle, taking its name from the famous Italian economist Vilfredo Pareto. Frequency is indicated by the vertical axis to the left, but it can also represent cost or another important unit of measure. Cumulative percentages of total occurrences, total costs or totals for a specific unit of measure are displayed on the vertical axis to the right. The cumulative function is a concave function because the values are sorted in descending order. Take the example below, to reduce procrastination by 78%, just solving the first three problems is enough. The purpose of a Pareto chart is to highlight the most important of the (usually important) factors.

History with Product/License of

Pareto charts can be used in quality control to identify the flaws that need to be fixed first in order to see the biggest overall improvement. It frequently reflects the most frequent causes of faults, the most prevalent kind of defect, the most common causes of customer complaints, and so forth. For each bar in the Pareto chart, Wilkinson (2006) developed a method that generates statistically based acceptance limits (akin to confidence intervals).

Usage of the tool, Benefits:

- Inventory management: The ABC inventory control system is based on the Pareto principle, which states that since 80% of the inventory movements in a warehouse come from 20% of the products, these items require the greatest attention.
- Sales: 20% of products account for 80% of closed sales, and 20% of the most devoted clients account for 80% of overall earnings, allowing for the development of more successful business and marketing strategies.
- Customer service: Since 20% of product failures are thought to account for 80% of customer complaints, precision optimization should be prioritized to lower incidences.
- Production control: Studying the 20% of flaws in a production that result in 80% of the bad effects of the procedures using the Pareto diagram helps to prioritize the improvement program.
- Human Resources: Since 80% of absences are mostly caused by 20% of collaborators, the 80/20 rule can be used to detect issues like absenteeism in the context of organizational development.

Advantages

- assists in locating and analysing the underlying causes of flaws or issues
- Organizations can address the most urgent issues first when eliminating flaws or faults.
- Calculate a problem's cumulative impact. A problem's cumulative impact is an effect that results from a problem occurring over a lengthy period of time.
- Organizations can use Pareto charts to determine what steps or actions are necessary to fix issues.

Disadvantages

- Only useful for locating or identifying the sources of a problem or problems; does not offer remedies to problems
- Only considers historical data
- Pareto charts cannot be used to depict quantitative data; they can only display qualitative data that can be observed.
- Pareto diagrams can improve one's ability to solve problems and make decisions.

Diagrams

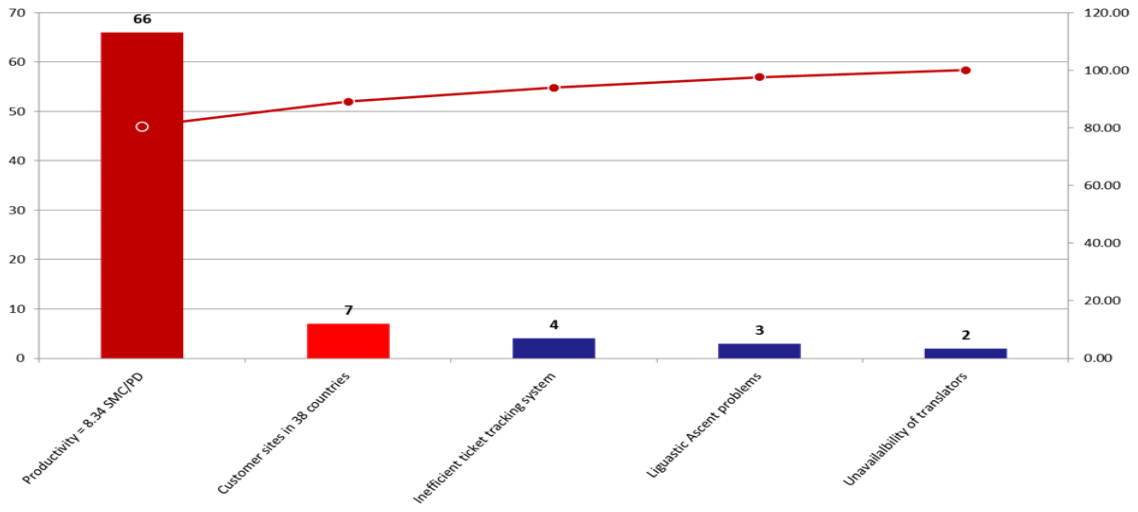

Figure 1: Pareto diagrams showing the top 80% problems for high schedule variance in a software project

2. Control Charts

Control charts are graphical diagrams used in production control to assess the stability of production processes and control quality. (ISO 7870-1) Hourly status is displayed on the graph and the presence of data deviating from the control limit line or normal trend is used to determine the occurrence of anomalies. Shewhart's own control charts (ISO 7870-2) and CUSUM (CUsUM) (or cumulative total control charts) (ISO 7870-4) are two types of control charts.

Control charts, often called Shewhart charts (after Walter A. Shewhart), process-behaviour charts, or simply control charts, are statistical process control tools used to assess whether a manufacturing or business process is under control. It would be more accurate to say that the graphical tool for statistical process monitoring (SPM) is the control charts. In situations where the underlying structure of the process distributions is understood, traditional control charts are mostly used to monitor process parameters. However, more sophisticated methods are now available, allowing for the monitoring of incoming data streaming even without being aware of the distributions of the underlying processes. Control charts without distribution are becoming more and more common.

History with Product/License of

While employed by Bell Labs in the 1920s, Walter A. Shewhart created the control chart. The company's experts have been working to make their telephony transmission systems more dependable. There was a greater commercial need to lower the frequency of breakdowns and maintenance because amplifiers and other equipment had to be buried underground. Engineers had begun to understand the value of minimizing variation in production processes by 1920. In addition, they understood that constant process modification in response to non-conformance merely increased variety and weakened quality. On May 16, 1924, Shewhart introduced the control chart as a tool for differentiating between common and unique sources of variation in an internal note. Shewhart framed the issue in terms of common and special causes of variation.

Shewhart's boss, George Edwards, recalled: " Dr. Shewhart prepared a little memorandum only about a page in length. About a third of that page was given over to a simple diagram which we would all recognize today as a schematic control chart. That diagram, and the short text which preceded and followed it set forth all of the essential principles and considerations which are involved in what we know today as process quality control." Shewhart has shown that in

order to predict future production and operate a process economically, a manufacturing process must be placed under statistical control, where only causal variation is possible. shared.

Through meticulously planned trials, Shewhart developed the foundation for the control chart and the idea of a state of statistical control. Shewhart used pure mathematical statistical theories, although he was aware that the "normal distribution curve"—a Gaussian distribution, often known as a "bell curve"—is typically produced by data from physical processes. In contrast to data from nature (Brownian motion of particles), he found that observed variance in manufacturing data did not always behave in the same way. Shewhart came to the conclusion that while all processes exhibit some degree of variation, some processes exhibit controlled variation that is inherent to the process, whilst others exhibit uncontrolled variation that is not always present in the causal system underlying the process.

W. Edwards Deming, who was then employed at the Hawthorne factory, learned about Shewhart's invention around 1924 or 1925. Later on, Deming worked at the US Department of Agriculture before becoming the US Census Bureau's math advisor. Deming emerged as Shewhart's work's leading defender and advocate during the course of the following 50 years. Deming provided statistical advice to the Supreme Commander for the Allied Powers following the defeat of Japan at the end of World War II. His continued involvement in Japanese culture and his lengthy tenure as an industrial consultant there helped spread Shewhart's ideas and the usage of the control chart throughout the Japanese manufacturing sector in the 1950s and 1960s.

Following the creation of the transistor in the 1950s, Bonnie Small worked in a company in Allentown. Produced up to 5000 control charts using Shewhart's methodologies to enhance plant performance in quality control. She published "The Western Electric Statistical Quality Control Handbook" in 1958, which was used by AT&T.

Usage of the tool, Benefits

99.7300% of all the points will be inside the control boundaries if the process is under control (and the process statistic is normal). Any findings outside the parameters or recurring patterns inside them imply the presence of a fresh source of variation—referred to as a particular cause variation—that was probably not anticipated. A control chart that "signals" the presence of a unique reason needs to be looked into right away because higher variation entails increased quality expenses.

The control boundaries are therefore crucial tools for making decisions. The control limits give information about the behaviour of the process; they are not fundamentally related to any specification targets or engineering tolerances. Because the process design can't actually produce the process characteristic at the desired level, the process mean (and subsequently the centre line) may not actually match the quality characteristic's set value (or target).

Control charts limit specification limits or goals due to the tendency of process participants (e.g. machine operators) to focus on achieving specifications while in fact, the least expensive course of action is to keep process variability as low as possible. Attempting to ensure that a process with a natural centre that is not the same as the objective is implemented according to the objective specification increases the variability of the process and significantly increases costs and is the cause of many problems. inefficient operation. However, process capability studies examine the relationship between the natural limits of processes (limits of control) and specifications. The purpose of control charts is to allow simple detection of events that indicate an increase in process variability. This simple decision can be difficult when process characteristics are constantly changing; Control charts provide statistically objective criteria for change. Once a change is detected and considered good, its cause must be identified and eventually the new way of doing things, where the change is bad, its cause must be identified and eliminated.

The purpose of adding warning limits or subdividing the control chart into zones is to provide early notification if something is amiss. Instead of immediately starting a process improvement effort to determine if a special cause is present, the quality engineer can temporarily speed up the sampling rate from the process output until it becomes clear that the process is really under control. Note that for three sigma limits, common cause variations lead to signals less than once in twenty-two points for asymmetric processes and about once in three hundred and seventy (1/370.4) points for normally distributed processes. The two sigma warning levels will be reached approximately once for every twenty-two points (1/21.98) plotted in the normally distributed data. (For example, the mean of sufficiently large samples drawn from virtually any fundamental distribution where variance exists is normally distributed, according to the central limit theorem.)

Advantages

In comparison to other QI tools, control charts have a number of advantages, including the ability to visualize process performance and variation across time. This makes it possible for you to spot patterns, cycles, or changes in the data. Additionally, control charts assist in Diagrams identifying common cause and special cause variation, which directs the proper course of action to enhance the process. For instance, if the process is under control, you should concentrate on redesigning the process to lower common cause variation. If the process is in control, on the other hand, you should look for and eliminate the causes of variance. Control charts can also assess the impact of adjustments or interventions on the process by contrasting data from before and after the change.

Disadvantages

There are certain restrictions and difficulties with control charts that may reduce their accuracy. For instance, in order to apply the SPC rules and assumptions, they need a stable and predictable process as well as enough data to calculate the control limits and detect relevant deviations. The process measure must also be operationalized and defined clearly, and a qualified and skilled team must use and understand them correctly. The control limits may not accurately reflect the underlying process variation if any of these conditions are not met, leading to false alarms or missed signals, inaccurate interpretations, or data that does not accurately reflect the performance and variation of the process.

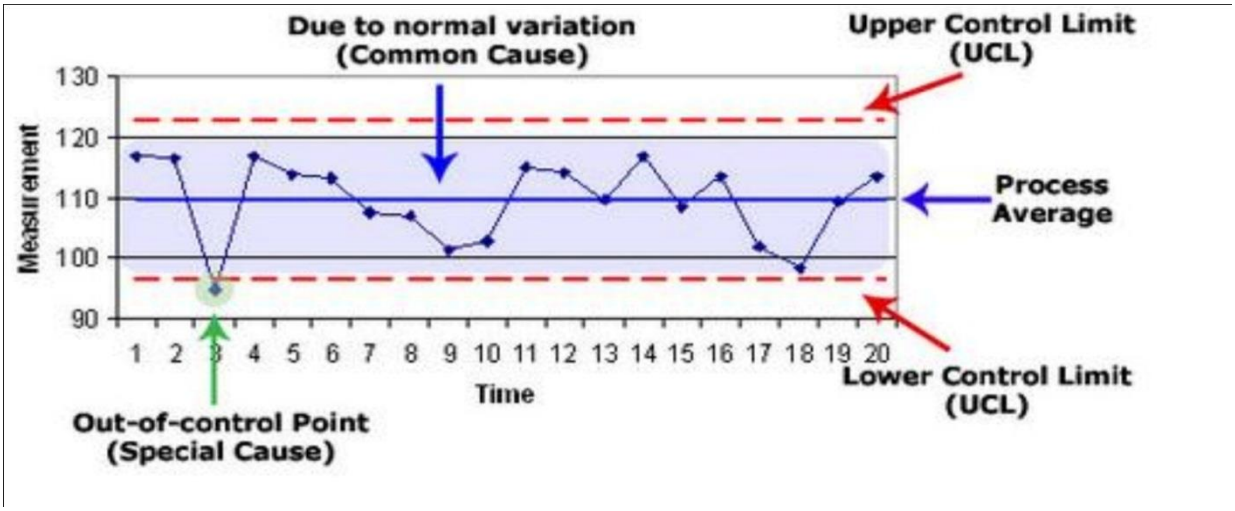

Figure 2: Control Charts Showing the Control Limits which helps to understand UCL and LCL.

We can see from the control chart in figure 2 above that the mean is 110. The Control Limits are in the range of 100 to 120.

3. Minitab

Minitab is a statistics package developed at the Pennsylvania State University by researchers

Barbara F. Ryan, Thomas A. Ryan, Jr., and Brian L. Joiner in conjunction with Triola Statistics Company in 1972. It began as a light version of OMNITAB, a statistical analysis program by National Institute of Standards and Technology. In addition to Minitab, Minitab, LLC also creates other software that may be utilized with Minitab. Quality Trainer is an eLearning program that teaches statistical concepts, Minitab Workspace offers project planning and visualization tools, and Minitab Engage is a tool for idea and innovation management as well as managing Six Sigma and Lean manufacturing deployments. Minitab Connect aids businesses in centralizing and organizing their data.

History with Product/License of

The first cloud-based version of Minitab's statistics software was released in October 2020. As of June 2021, the MacOS version of Minitab (19.x) is no longer maintained and the Minitab Desktop program is only available for windows.

Researchers Barbara F. Ryan, Thomas A. Ryan, Jr., and Brian L. Joiner created Minitab at Pennsylvania State University in 1972. The Triola Statistics Company provided financial support for the study. It started off as a simplified version of NIST's OMNITAB, a statistical analysis tool designed by Joseph Hilsenrath for the IBM 7090 between 1962 and 1964. There hasn't been much progress since the documentation for the most recent version of OMNITAB, OMNITAB 80, was last updated in 1986. Minitab, LLC, a privately held business with its headquarters in State College, Pennsylvania, distributes Minitab. Minitab LLC requested and received between $5 million and $10 million under the pay check Protection Program in 2020 during the COVID-19 epidemic in order to prevent having to lay off 250 workers. The subsidiaries of Minitab LLC were located in the UK, France, Germany, Hong Kong, and Australia as of 2021.

Usage of the tool, Benefits:

- Minitab's main feature and value is unquestionably how user-friendly it is. Minitab was created with the goal of keeping things straightforward for the user while also being effective on the backend.
- You can easily generate graphs using statistical data, which Minitab can process in big quantities. To display the data as graphs, no more calculations are needed. On the other hand, MS Excel may be used to assemble and manage vast amounts of data, but because it has the ability to arrange the data in graphs, the process is significantly more difficult.
- Minitab offers a highly tidy and well-organized user interface. This is especially helpful when working with vast quantities of data sets and a variety of graphical representations of those data sets.
- Minitab provides a wide range of choices for representing and visualizing data. Statisticians and other people in related fields who engage in data analysis will find these options to be very helpful.
- In terms of forms, it gives variety. That refers to the fact that Minitab files may be exported to a variety of formats, which can then be utilized for presentations or for shared with coworkers and peers. This adaptability is particularly useful in work environments.

Advantages

- Strong statistical analysis tools: Minitab is well known for its powerful statistical analysis tools. It provides a large range of statistical tests and processes, enabling users to thoroughly examine their data. Minitab offers the tools you need to properly and quickly analyse your data, whether you need to do a t-test, chi-square test, or run a regression analysis.
- User-friendly interface: Minitab's user-friendly interface is one of its significant benefits. Even for those with little experience in statistics, the software is made to be simple to use and intuitive. A wide range of users can utilize Minitab's menu-driven interface and graphical features to execute complicated studies without substantial programming knowledge.
- Data visualization and graphical analysis :are made easier by a range of graphical tools that Minitab provides. To graphically depict their data, users can produce

instructive charts, scatterplots, histograms, and control charts. A deeper comprehension of the data and its ramifications is made possible by these visualisations, which aid in spotting trends, patterns, and outliers.

- Tools for quality improvement: Minitab is a popular tool for quality improvement, especially in Six Sigma projects. It offers a variety of tools, including design of experiments, process capability analysis, Pareto charts, and control charts, which are crucial for process optimization and quality control. Because of its quality improvement features, Minitab is a priceless tool for businesses looking to optimize their procedures and cut down on errors.

Disadvantages

- Minitab has restricted programming capabilities compared to some other statistical software tools, despite having an intuitive user interface. Its scripting capabilities may be limited for advanced users who like to develop their own scripts or automate repetitive chores. The built-in functionality and graphical user interface of Minitab, however, are more than adequate for the majority of users' analytical requirements.
- Minitab may have a challenging learning curve for those who are new to statistical analysis software. Although the user interface is created to be intuitive, some level of statistical knowledge is necessary in order to comprehend the underlying statistical ideas and utilize its capabilities. However, users may get past this initial obstacle and utilize all of Minitab's capabilities with enough practice and instruction.
- Lack of sophisticated data manipulation tools: Although Minitab is excellent for statistical analysis, it could not have the same sophistication of sophisticated data manipulation tools as other software programs. It may be necessary to use additional tools or computer languages to complete tasks like data cleansing, transformation, and advanced data querying. To meet their individual demands, users with extensive data processing requirements would need to supplement Minitab with additional applications.
- Minitab primarily concentrates on statistical analysis and quality improvement. e) Limited support for non-statistical analysis. If you need considerable non-statistical analysis, such as text mining, machine learning, or complex data visualization, you might find Minitab's capabilities to be limiting. In these circumstances, it is wise to look into alternative software solutions that can meet your particular analysis demands.

Diagrams

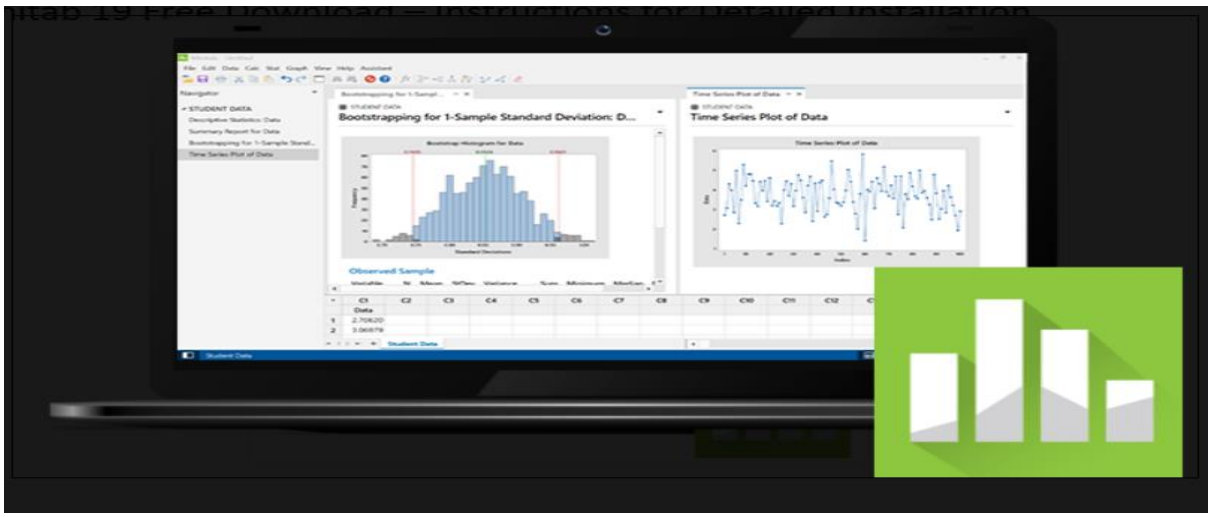

Figure 3: Minitab screen showing an intuitive and user-friendly environment for conducting data analysis, statistical modelling, and quality improvement tasks

4. Linear Regression Equations

When modelling the relationship between a scalar answer and one or more explanatory factors (also known as dependent and independent variables) in statistics, linear regression is a linear approach. Simple linear regression is used when there is only one explanatory variable, and multiple linear regression is used when there are numerous variables. As opposed to multivariate linear regression, which predicts numerous correlated dependent variables as opposed to a single scalar variable, this phrase is more specific.

In linear regression, linear predictor functions are used to model relationships, with the model's unknown parameters being estimated from the data. These models are referred to as linear models. The conditional mean of the response is typically considered to be an affine function of the values of the explanatory variables (or predictors); the conditional median or another quantile is occasionally employed. In common with all other types of regression analysis, linear regression concentrates on the conditional probability distribution of the response given the values of the predictors rather than the joint probability distribution of all these variables, which is the purview of multivariate analysis. The first sort of regression analysis that underwent in-depth research and saw extensive use in real-world scenarios was linear regression. This is because models whose unknown parameters rely linearly on them are simpler to fit than models whose unknown parameters depend non-linearly on them, and because it is simpler to determine the statistical characteristics of the resulting estimators.

Linear Regression Equation

The correlation coefficient illustrates how closely two variables are related to one another. This coefficient's range is from -1 to +1. This coefficient demonstrates the degree to which the observed data for two variables are significantly associated.

A line equation for linear regression looks like this:

$Y = a + bX$

where X is the independent variable and is represented along the x-axis.

The dependent variable, Y, is represented by a line on the y-axis.

A is the intercept (the value of y when x = 0), and b is the line's slope.

Linear Regression Formula

Linear regression shows a linear relationship between two variables. The linear regression equation is similar to the slope formula we learned previously in previous classes, such as a two-variable linear equation. It is given by;

$Y= a + bX$

Now, here we need to find the value of the slope of the line, b, plotted in the scatter plot and the intersection, a.

Linear Regression Formula

$$a = \frac{[(\sum y)(\sum x^2) - (\sum x)(\sum xy)]}{[n(\sum x^2) - (\sum x)^2]}$$

$$b = \frac{[n(\sum xy) - (\sum x)(\sum y)]}{[n(\sum x^2) - (\sum x^2)]}$$

History with Product/License of

Legendre (1805) and Gauss (1809) used least squares linear regression to obtain a decent rough linear fit to a group of data points in order to forecast planetary motion. It was Quetelet who popularized the method and made considerable use of it in the social sciences.

Usage of the tool, Benefits

Market analysis

By identifying the correlations between a number of quantitative variables, such as social media engagement, pricing, and sales volume, a regression model can be used to ascertain how products perform in the market. With the help of this information, you can use particular marketing techniques to maximize sales and raise money. For instance, you may determine how price impacts sales and use it to gauge the strength of the relationship between the two variables using a straightforward linear model.

Financial analysis

To assess a company's operational performance and project returns on investment, financial analysts utilize linear models. In the capital asset pricing model, which investigates the relationship between anticipated investment returns and corresponding market risks, they also employ it. It aids in judgments about whether or not to invest in the asset by demonstrating to businesses whether an investment has a reasonable price.

Sports analysis

This entails the use of statistics by sports analysts to assess a team's or player's game-day performance. They may compare teams and players using this data, and they can also give their followers important information. To provide team managers with recommendations on game locations and ticket pricing that will maximize earnings, they can also utilize this data to forecast game attendance depending on the standing of the competing teams and the size of the market.

Environmental health

Regression model is used by experts in the field to analyse how natural elements like soil, water, and air relate to one another. The connection between the quantity of water and plant development serves as an illustration. Environmentalists might use this to forecast the impacts of air or water pollution on the ecosystem.

Medicine

Regression model can be used by medical researchers to analyse the link between independent parameters, like age and body weight, and dependent characteristics, like blood pressure. This can assist in exposing the diseases' risk factors. They can identify high-risk patients and encourage healthy lifestyles using this information.

Advantages

- A very straightforward procedure, linear regression can be used to provide results that are adequate. In addition, compared to other complicated methods, these models may be trained quickly and effectively even on systems with less CPU capability. Comparing linear regression to some of the other machine learning techniques, linear regression has a significantly lower temporal complexity. The linear regression's mathematical formulae are also quite simple to comprehend and interpret. As a result, linear regression is fairly simple to learn.
- Performance on datasets with linear separability Finding the nature of the relationship between variables is frequently done using linear regression, which almost perfectly fits linearly separable datasets.
- Overfitting occurs when a machine learning model fits a dataset extremely tightly and hence also includes noisy data. This has a detrimental effect on the model's functionality and lowers its test set accuracy.
- Regularization is a method that can successfully reduce a function's complexity and lower the danger of overfitting. It is simple to use and effective.

Disadvantages

- Underfitting: An issue that occurs when a machine learning model is unable to accurately represent the data. When the hypothesis function cannot adequately fit the data, this often happens. An anomaly or extreme value that deviates from the other data points in the distribution is an outlier in a data set.
- Outliers: Data outliers can severely impair a machine learning model's performance and frequently result in models with poor accuracy.

Diagrams

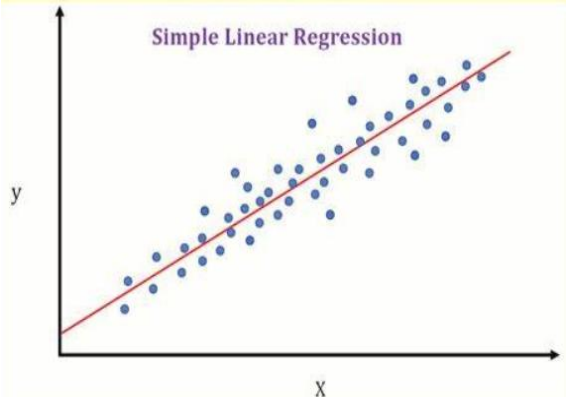

Figure 4: Scatter diagram showing the line of regression.

An example from our research is ;

Y (PG) = ($X1$ (SV),$X2$ (EV),$X3$ (PSDD),$X4$ (IDD),$X5$ (PROD))

Where PG = Profitable Growth, SV = Schedule Variance, EV = Effort Variance PSDD = Post Shipment Defect Density, IDD = Internal Defect Density, PROD = Productivity

5. Goal Question Matrix (GQM)

Brief Description of the Tool

The term "GQM" stands for "goal, question, metric," and it refers to a well-known goal-oriented approach to software measurements for enhancing and assessing software quality.

On three levels, GQM defines a measuring model:

1. Conceptual level (Goal)

A goal is established for an object for a range of factors, in consideration of different quality models, from different perspectives, and in relation to a particular context.

2. Operational level (Question)

In order to characterize the evaluation or accomplishment of a particular goal, a set of questions is used to define models of the studied object.

3. Quantitative level (Metric)

Each question has a set of metrics attached to it based on the models in order to provide a quantifiable response.

History with Product/License of

Victor Basili, who oversaw Dr. David M. Weiss' Ph.D. thesis at the University of Maryland, College Park, and the Software Engineering Laboratory at the NASA Goddard Space Flight Centre, have championed GQM. Albert Endres' work at IBM Germany served as an inspiration for Dr. Weiss' work.

Usage of the tool, Benefits,

The GQM approach can have a number of benefits for software quality management, including making quality goals clear to the team and stakeholders, designing and choosing metrics that are appropriate to the quality goals and context, monitoring and evaluating software quality in a methodical and objective manner, identifying and prioritizing areas for improvement, and demonstrating and justifying software quality accomplishments.

SWOT Analysis

Advantages

- Structured methodology: GQM offers a methodical and structured methodology for establishing objectives, generating inquiries, and creating measurements. The organization and alignment of the measuring process with the objectives are ensured by this framework.
- Alignment: GQM ensures that the organization's overarching goals and the metrics used to assess project performance are in line with one another. It creates a direct connection between broad objectives and the particular metrics used.
- Customization: GQM enables the measurement process to be tailored to the particular requirements of a project or organization. It is versatile and flexible since it can be adjusted to many contexts and areas.
- Clarity: GQM encourages clarity by decomposing broad objectives into particular issues that must be addressed. Understanding what has to be measured and why is made easier by this clarity.

Disadvantages

- Structured methodology: GQM offers a methodical and structured methodology for establishing objectives, generating inquiries, and creating measurements. The organization and alignment of the measuring process with the objectives are ensured by this framework.
- Complexity: Despite the fact that GQM offers a systematic approach, developing an efficient GQM can be difficult and time-consuming, especially for individuals who are unfamiliar with the methodology.
- Subjectivity: Creating questions and setting measurements can both be subjective processes. Goals and questions could be interpreted differently by several people, which could result in a variety of measurement methodologies.
- Resource-intensive: The GQM process must be developed and put into use. Resources needed include time, knowledge, and instruments for

data collecting and analysis. For groups with little resources, this may be difficult.

Diagram

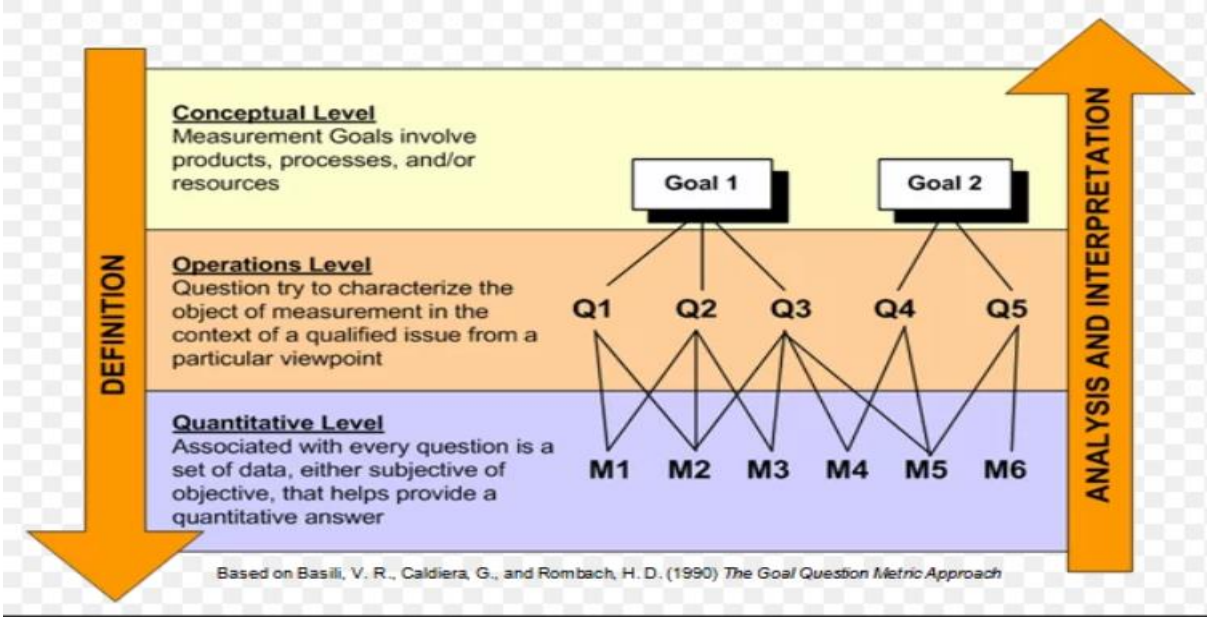

Figure 5: GQM[6]

6. Balanced Score Card (BSC)

A strategic management performance indicator known as the balanced scorecard (BSC) is used to identify and enhance various internal business activities and the results they have on the outside world. Balanced scorecards are a widespread tool used by businesses in the United States, the United Kingdom, Japan, and Europe to measure and provide feedback to organizations. In order to provide quantitative results, data collecting is essential because managers and executives must acquire and analyse the data. The decision-making of company personnel for the future of their organizations can be improved with the help of this knowledge.

History with Product/License of

The balanced scorecard was initially developed by business leader and theorist Dr. David Norton and accounting professor Dr. Robert Kaplan. It was initially published in 1992 in the Harvard Business Review article "The Balanced Scorecard—Measures That Drive Performance." Kaplan and Norton collaborated on a one-year project involving 12 high-performing businesses. Their study modified earlier performance indicators to incorporate nonfinancial data.

Usage of the tool, Benefits

The use of a balanced scorecard has various advantages. For instance, rather than needing to manage various technologies, the BSC enables firms to combine information and data into a single report. When conducting evaluations to enhance procedures and operations, managers can do so while saving time, money, and resources.

Scorecards give managers important information on the level of service and product that their company offers in addition to its financial performance. Executives can train staff members and other stakeholders and offer support and guidance by monitoring all of these metrics. In order to achieve their future objectives, this enables them to convey their priorities and aims.

BSCs also assist businesses in reducing their dependency on inefficient processes, which is another important advantage. Suboptimization describes this situation. This frequently leads to decreased output or productivity, which can cause increased expenses and revenue loss as well as damage to brand names and reputations of businesses.

Advantages

- Organizational goals are presented in the Balanced Scorecard as a one-page chart divided into relevant categories.
- It enables businesses to fill the gap between their stated missions or broad objectives and the ways in which their everyday operations contribute to those missions or objectives. The improvement of technical support performance in accordance with the Service Level Agreement or beyond the SLA can be linked to a BSC aim of satisfying the client.
- BSC makes innovation and techniques for process improvement like six sigma and lean manufacturing a company objective. Additionally, it guarantees that the customer's voice is given equal weight.
- It does not preclude alternative techniques for process optimization or business reporting. Six sigma initiatives logically belong in the "learn and innovate" category. Financial scorecard goals are simply met by the financial department by using financial standards, such as Sarbanes Oxley, or by implementing them to satisfy a financial scorecard goal.
- A balanced scorecard can offer a visual way to show how several objectives are connected. Sales growth enhances the financial section's profit or sales targets. The "voice of the customer" goal is achieved by better customer service.

Disadvantages

- Performance on the balanced scorecard is arbitrary. It cannot be measured other than through polls or management opinion, unlike quality levels. A "learn and innovate" quota that requires a certain number of training hours each year doesn't necessarily indicate that all employees complete courses that will benefit their employment or that taking classes only to meet the requirement is preferable than working on an assembly line. Since morale is not necessarily a manager's responsibility, demanding good employee morale can be detrimental to managers. It is counterintuitive to aim for high morale while also making layoffs to save money.
- It excludes risk management and direct financial analysis of economic value. Opportunity cost calculations are not automatically included when choosing goals for the Balanced Scorecard.
- BSC can introduce a new type of reporting without necessarily enhancing quality or financial results, which might give the impression that it is an additional set of reporting that adds little value or, worse, a diversion from realizing objectives.
- BSC goals that are too amorphous are simple to achieve but difficult to assess.

Diagrams

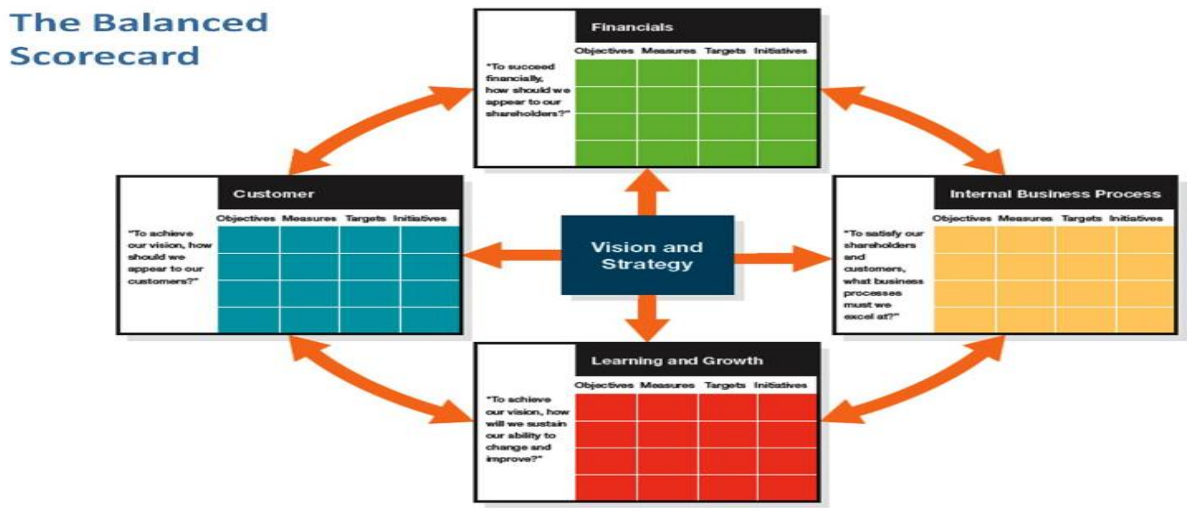

Figure 6: BSC depicting the entire governance model of an organization. These are the pillars for the Vendor Selection Algorithm.

7. Goal Decomposition Matrix (GDM)

In project management and systems engineering, a Goal Decomposition Matrix (GDM) is a tool that is used to visually illustrate the links between different goals, sub-goals, and tasks inside a complicated project or system. It facilitates the breakdown of large-scale goals into more manageable, more attainable parts, enabling better understanding, planning, and coordination of operations.

The GDM often takes the form of a matrix, where the rows correspond to the project's or system's primary goals or objectives and the columns to the specific sub-goals, tasks, or activities that are required to reach those goals. Information regarding the connections between the goals and the tasks is contained in the intersections of the rows and columns. These connections may take many different forms, including:

Dependence: Shows that the accomplishment of one task or sub-goal depends on the success of another task or sub-goal.

Contribution: Demonstrates how a task or sub-goal helps a higher-level goal be achieved.

Conflict: Indicates that two objectives or sub-goals cannot be pursued simultaneously without having a negative impact on one another.

Project managers and teams can more easily comprehend the hierarchy of objectives and tasks, pinpoint crucial dependencies, control disputes, and allocate resources by using a GDM. Additionally, it facilitates a better understanding of how various components are interconnected by outlining the overall structure of the project to stakeholders and team members.

GDMs are a helpful tool for planning and monitoring progress throughout the lifecycle of a project, ensuring that each phase is in line with the overall goals and that adjustments may be made as necessary to keep on course.

Usage of the tool, Benefits

Defining High-Level Goals: To start, decide on the system's or project's primary high-level goals or objectives. These are the main results you wish to accomplish.

Identifying Sub-Goals and Tasks: List the sub-goals and tasks that each high-level goal need to be accomplished. The matrix's columns and rows each stand for a certain activity or aim.

Establishing Relationships: Fill in the intersections of the matrix's rows and columns to show the connections between the objectives and the tasks. This may involve interdependencies, in which the performance of one task depends on the success of another, or contribution connections, in which tasks aid in the achievement of more important objectives.

Managing Dependencies: You can spot essential paths and potential bottlenecks by visualizing dependencies. Scheduling and resource allocation are aided by this.

Conflict Resolution: The matrix can be used to identify any tasks or goals that clash or contradict one another. Conflict resolution is made simpler by using a clear visual representation.

Communication: To give stakeholders and team members a clear picture of the project's structure and goals, the matrix can be distributed. Effective communication and comprehension are aided.

As for how this idea came to be, it's possible that the contributions of numerous specialists in domains like project management, systems engineering, and operations research over time helped to shape the idea of breaking down goals and activities for better project management and system knowledge. The Goal Decomposition Matrix, however, cannot be "developed" by any one individual or group of individuals.

Advantages

- Clarity and Visualization: A well-designed GDM may offer a clear and visual depiction of the hierarchy of objectives, sub-objectives, and tasks, making it simpler for teams to comprehend the connections and dependencies between various parts.
- Complexity Decomposition: GDMs assist in decomposing complex projects or systems into manageable parts, which facilitates planning, resource allocation, and progress monitoring.

- Alignment with Objectives: GDMs guarantee that all tasks and sub-objectives are in line with the overall goals. This stops tasks from diverging from the project's overarching objectives.
- GDMs make it simpler to discover task relationships and important routes, enabling more effective resource scheduling and allocation.

Disadvantages

- Limited to Structure: GDMs tend to concentrate exclusively on the hierarchical organization of objectives and tasks, potentially ignoring other crucial factors like resource limitations, budget, and risk management.
- Subjectivity: Differences in how team members interpret goal breakdown and the connections between objectives and tasks could result in discrepancies in the matrix.
- Information overload: In complicated projects, the GDM may become too complicated to manage and comprehend due to the abundance of goals, sub-goals, and activities.
- Lack of Context: GDMs may fail to account for the project's larger context, which may include outside influences, market trends, or strategic considerations.

Diagrams

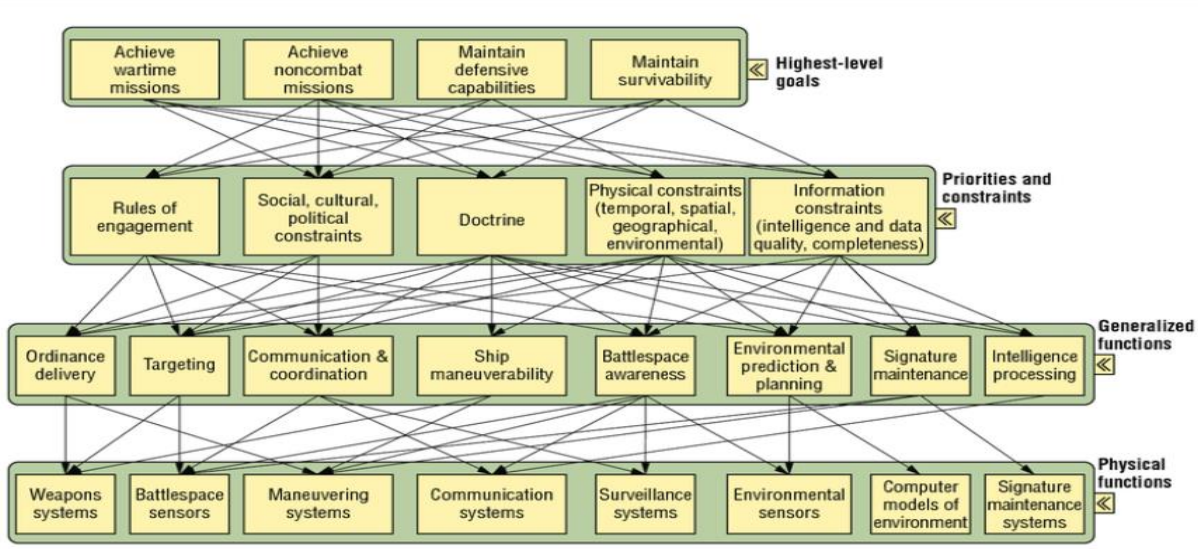

Figure 7: GDM showing the break down high-level goals or objectives into more specific and actionable sub-goals or tasks

A Goal Decomposition Matrix, also known as a Goal Hierarchy or Goal Dependency Matrix, is particularly useful for project management, especially in the IT industry, where complex projects often involve multiple stakeholders, diverse tasks, and interdependencies. The matrix helps establish a clear hierarchy of goals and facilitates effective planning, delegation, and tracking of project activities.

8. Fishbone/Ishikawa diagram

Brief Description of the Tool

Drawing cause-and-effect diagrams, also referred to as "Fishbone Diagrams," is a common way to organize a lot of information. These diagrams show links between events and their potential or actual causes and serve as a way to spark ideas about why the issue is occurring and the potential effects of that cause.

The cause-and-effect analysis enables problem solvers to think more broadly and consider a problem's bigger picture. Diagrams of causes and effects can show either causes that obstruct the intended state or beneficial variables required to achieve the desired state.

The fishbone diagram, sometimes referred to as a cause-and-effect diagram or an Ishikawa diagram, is a visual representation of the various causes of an issue. It also aids in the

identification of stakeholder opinions regarding the causes of problems, allowing us to quickly group opinions into themes for analysis or additional data collection. The 5-whys method is frequently combined with the fishbone graphic.

History with Product/License of

Sakichi Toyoda invented the system in the beginning, and the Toyota Motor Corporation employed it as its manufacturing processes developed. As part of the introduction to the Toyota Production System, it is a crucial part of the problem-solving training that is provided. The five whys method, according to Taiichi Ohno, the creator of the Toyota Production System, is "the basis of Toyota's scientific approach by repeating why five times the nature of the problem, as well as its solution, becomes clear." Beyond Toyota, the tool is now widely utilized in Kaizen, lean manufacturing, lean construction, and Six Sigma. The five whys were not created for root cause analysis; rather, they were created to explain why new product features or production procedures were required.

It takes on other shapes in other companies. Under Ricardo Semler, Semco expands the "three whys" method to include goal-setting and judgment.

Usage of the tool, Benefits

A cause-and-effect analysis encourages and enlarges thinking about prospective or actual causes and makes it easier to look more closely at specific reasons. A cause-and-effect analysis aids in establishing agreement on causes since it allows for everyone's thoughts to be represented on the diagram. It can be beneficial to concentrate attention on the procedure where a problem is occurring and to enable the useful use of information obtained from reported events.

- When determining potential sources of an issue
- When it's challenging to identify the root causes or contributing components of a system failure
- Most helpful as a team process for brainstorming collaboratively

SWOT Analysis

Advantages

- Utilizing a fishbone diagram is quite simple. The method is easy to learn and utilize, just as 5-Whys and brainstorming (which can be used to construct the "bones").
- The second method is visual. It is simple to identify what the researcher believes to be the primary issue (the fish's head), the primary elements affecting performance (the main bones connected to the spine), and the alternative reasons (the minor bones). The cause and effect relationship that the researcher wants to convey is depicted in a reasonably simple way using a fishbone diagram.
- Fishbone diagrams have been used for more than 50 years. It was undoubtedly one of the first methods created to aid problem solvers in comprehending a problem's root causes.

Disadvantages

- The method is based on the cause-and-effect method of root cause analysis. We have listed various disadvantages of cause and effect in earlier posts. These three articles, for instance, describe a number of the problems with cause and effect analysis.
- No instructions were provided for making the fish's bones. The knowledge of the investigator or investigating team affects how the bone structure is constructed. Additionally, as Barb Carr points out in the article below, most (Or should I say most?) investigators lack training in the fields of human factors and the causes of human errors. Because they lack human factors guidance to go beyond their understanding of human error, the bones on their Fishbone Diagrams represent their best estimates of the causes of human errors.

Diagrams

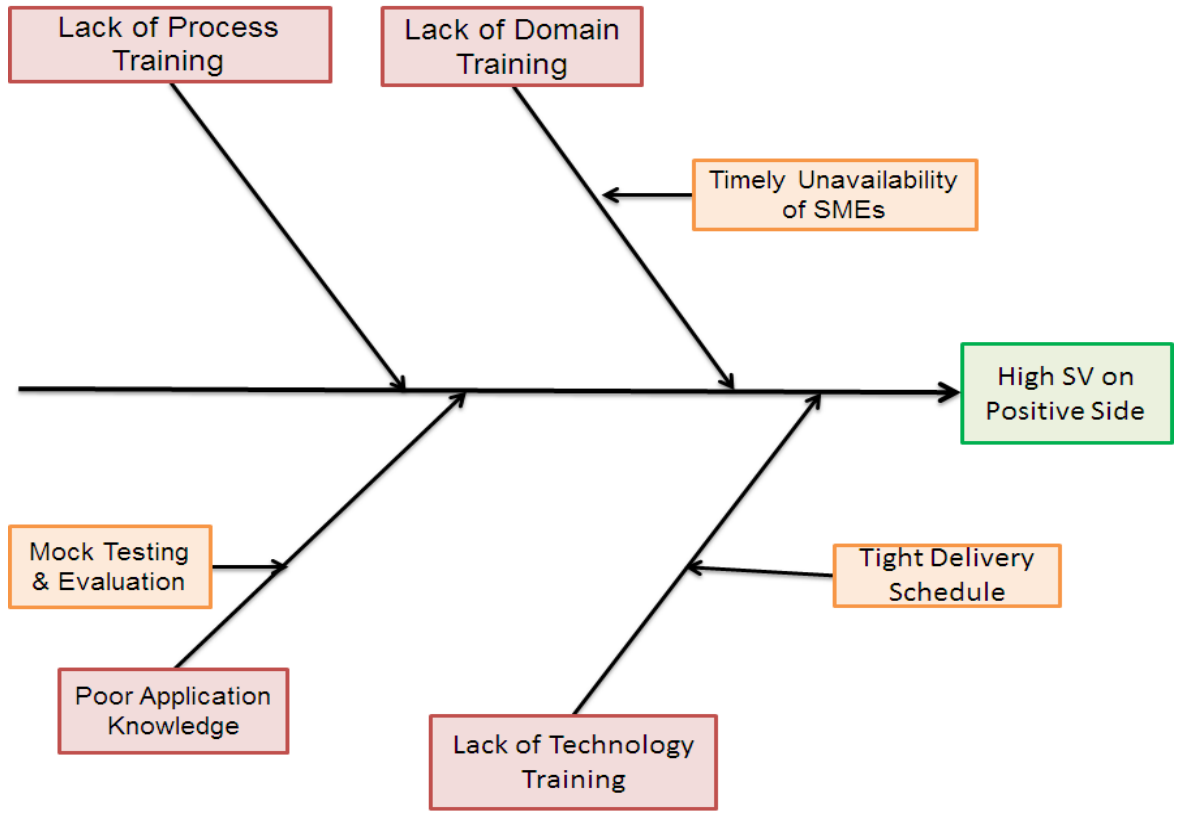

Figure 8: Failure Mode & Effects Analysis using the Fishbone diagram depicting the root cause of the problem. E.g. Failure in sick industries, Failure in Vendor selection etc.

Conclusion:

The journey of doctoral and post-doctoral research is one of perpetual exploration, an odyssey where tools, techniques, and utilities serve as guiding stars, illuminating the path toward intellectual excellence. It has been proved in the research that the above tools are very effective. Research cannot go ahead without usage of the tools. All the scholars (including the authors) have used these tools extensively in doctoral as well as post-doctoral research. These tools are effective, precise and flawless.

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