Process Dynamics, Variations and Controls in Software Engineering

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Abstract

Business operations are always under the influence of variations due to change in customer needs, market demands, internal processes and technology upgrades. These changes have direct impact on the performance of IT processes cascading down to the quality of products/services. In order to mitigate the adverse effects due to the variations of the aforementioned, organizations need to understand the concepts of software process dynamics and process controls.

Variations in IT processes are due to the factors affecting the process equilibrium. The enforced process controls are often not sensitive to these factors. This paper concentrates on the theory of software process dynamics and process variation including the importance of process controls to ensure process equilibrium.

This paper focuses on how the understanding of process variation and controls are useful in sustaining and improving process capability. This paper discusses the degree of association between Process and Quality through a Process Quality Relationship (PQR) Matrix that helps in managing the processes and sustaining the product/service quality.

This paper expands the possible ways and means to define and develop organizational process assets from a Total Quality Management perspective. This paper details an approach named SDICC (Strategy, Design, Implementation, Control and Continuous improvement) that provides guidance towards designing the processes and sustaining the improvements.

Biography

Shivanand Parappa is a Senior Consultant at Cognizant Technology Solution, currently working with Process and Quality Consultancy team. He has over 16 years of experience in Manufacturing / Software Quality Management and worked in various positions ranging from Industrial Engineer to Quality Manager. In his previous assignments, he played a key role in implementation of management system models like CMMI, ISO-9001, ISO-14001, OHSAS-18001, International Quality Rating Systems (IQRS). He has extensively worked on driving process improvement projects through Six Sigma and Lean methodologies to deliver tangible results.

Prior to Cognizant he worked with Patni Computer Systems, Tata Consultancy Services, Sterlite Industries and Grasim Industries. Shivanand holds a Bachelors degree in Industrial Engineering and a Masters degree in Production Engineering. He is a certified professional with Six Sigma Black Belt (DMAIC and DFSS), PMP and PRINCE2 Practitioner.

1 Introduction

Business operations are always under the influence of variations due to change in customer needs, market demands, internal processes and technology upgrades. These changes have direct impact on the performance of IT processes cascading down to the quality of products/services. In order to mitigate the adverse effects due to the variations of the aforementioned, organizations need to understand the concepts of software process dynamics and process controls.

Process helps an organization's workforce to meet business objectives by helping them to work smarter, not harder, and with improved consistency *[CMMI-DEV v1.3 2010]*. Processes are critical entities in an organization and its operational success is tied with the effective performance of the processes. One of the never ending challenges for an organization is to act on customer requirements and translate them into product or service with agreed quality attributes at low cost. The actions involved in conversion of the requirements to products/services are enabled and supported by well defined processes coupled with adequate resources. Processes can be grouped and classified into: core; enabling; governance; or support processes. This classification is only to bring the distinctions in the organization process asset instead of indicating its priority or ranking. Each of the organizational processes has equal importance with respect to achieving the objectives and goals of the organization.

"A process is a set of activities that are interrelated or that interact with one another" [ISO-9000:2005]. During the execution of process, the supplied inputs are converted into desirable output which may be intermediate or final products/services depending on the complexity of the process. Monitoring and control actions are imposed on the process to address deficiencies found in the process output. The variation in process performance *"voice of the process" [Howard Gitlow 2009]* is measured in terms of efficiency (output quantity against the target) and effectiveness (output quality against expected). Necessary actions are executed on activities within the process and supplied inputs to minimize or eliminate the variations. On the other hand, changing customer needs *"voice of the customer" [Kai Yang 2007]* are captured and incorporated accordingly into supplied inputs to meet customer expectations.

The following block diagram (Figure1) depicts the process model with closed loop feedback mechanism along with the changing customer needs (voice of the customer) and variation in process (voice of the process).

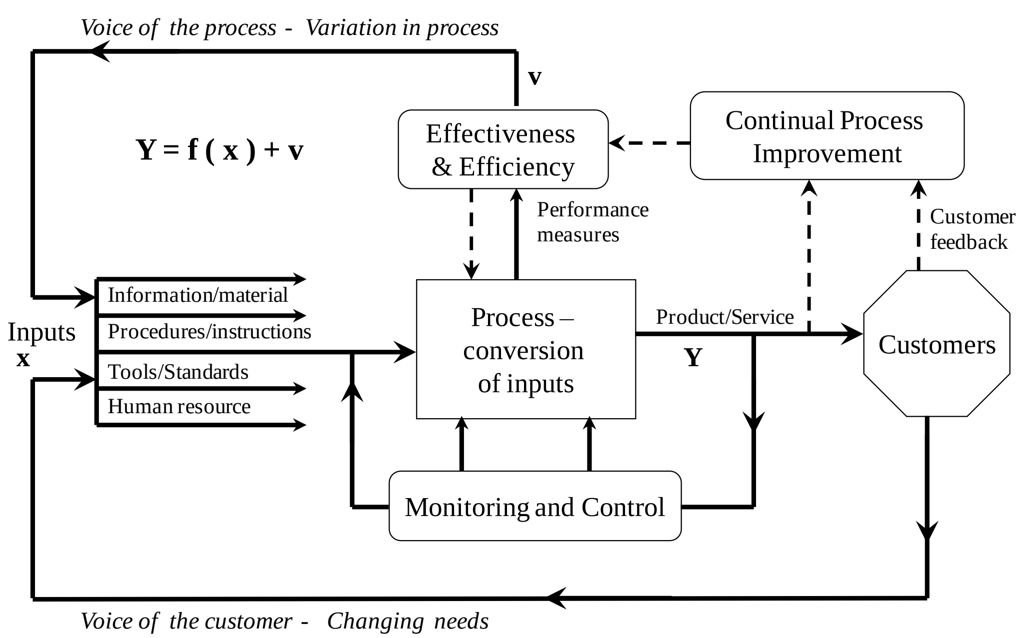


Figure 1 Closed loop process mechanism

From experience, it is observed that product/service quality is directly proportional to the process quality with some amount of inherent process variations due to common causes. *"The quality of a system or product is highly influenced by the quality of the process used to develop and maintain it" [CMMI-DEV v1.3 2010]*. From Six Sigma perspective, this relationship generally expressed through following concept *[Craig, Bruce and Terry 2006]:*

$$\mathbf{Y = f(x) + v}$$

Product/service quality, $\mathbf{Y}$, is function of process quality $\mathbf{x}$ (supplied inputs, activities and controls) with a certain degree of inherent process variations $\mathbf{v}$. For example, quality (defect free software) $\mathbf{Y}$, depends on the parameters $\mathbf{x}$ (requirement clarity, design approach, coding process, test cases and review methods) with some inherent process variations $\mathbf{v}$ (people skill level in coding and reviews).

2 Process dynamics

Among the various engineering domains, software engineering is very peculiar due to its dynamic nature of operations and variations in process implementation. One of the reasons for varied process dynamics is that software engineering processes are heavily dependent on rapid changing technologies and involvement of human beings rather than machines. From a physics point of view, dynamics is a branch of mechanics dealing with motion of material bodies under the action of given forces. This definition holds good for software engineering also where flow of information and processes are under the influence of forces like change in business operations, customer needs, technology, etc. Software process dynamics refers to the factors affecting software processes over a time period. It is also an approach to understanding the behaviour of processes based on the impacts of external and internal factors.

The dynamics of software processes has been explored by process practitioners to understand its mechanism. Due to competitive market and increased economic pressure, the ability to understand about dynamics and complex software development processes has become increasingly valuable for decision making. Process instability is due to various factors such as:

- Combined effects of schedule targets
- Communication overhead
- Changing business conditions
- Requirements volatility
- People experience
- Work methods such as reviews and quality assurance activities
- Task underestimation and organizational shifts.

Because of these factors, the adverse effects of process dynamics for individual sub-processes aggregate to the parent process level causing a large impact on intermediate/final deliverables and products/services.

To understand overall process dynamics, it is required to decompose processes into sub-processes and identify the associated forces at each sub-process level. The relationship between parent and sub-processes can be expressed in terms of a theoretical equation as shown below.

$$\sum_{i=1}^{n} \mathbf{Pdy_i = pdy_1 + pdy_2 + pdy_3 + \ldots + pdy_n}$$

Where, $\sum \mathbf{Pdy}$ is overall process dynamics,

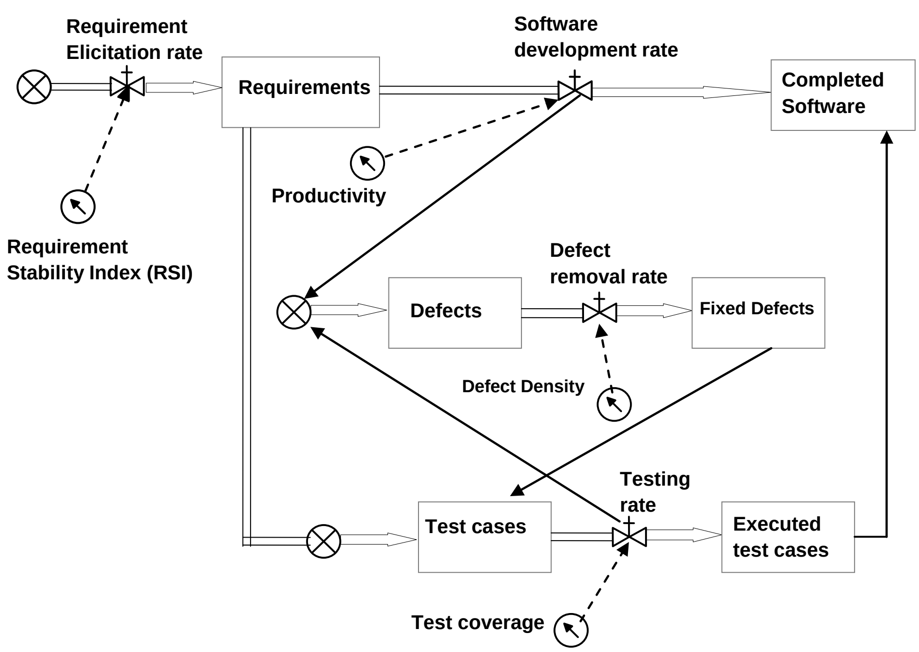
$\mathbf{pdy_1 + pdy_2 + pdy_3 + \ldots + pdy_n}$ are process dynamics of each sub-process and

$\mathbf{n}$ is number of sub-processes

Process dynamics relates to variation in the process performance measurement/metric (like productivity, effort and cost) of a process. Process metrics could be critical to quality or process parameters through which a product or service accepted by customers. In-depth understanding of behavior of sub-processes helps in establishing process performance (prediction) models which can be used to calculate the expected performance level of a parent process based on current performance level of the sub-process. For example, performance of peer review process (measured as overall defect density) is associated with performance of sub-processes like design review and code review and also technical experience of the people involved.

From the above equation, we can see that overall process dynamics is the sum of cumulative variations of individual process or sub-processes. Variations in processes are due to factors affecting the process equilibrium which are not sensitive to the currently enforced process controls. Most of the time, it is quite possible that controls are not adequate to minimize the effect of the factors causing process turbulence and not tested for their significance before deployment. Requiring processes to bear the impact of process variations without producing an adverse effect on performance is a key requirement for process definition. In order to establish rigorous controls over the defined processes, a detailed study and in-depth investigation of the causes for process variation are required.

The following schematic diagram (Figure 2) represents a simple process dynamics model for software development and its interrelated sub-process components (shown in boxes).



Legend:

Input entry point

Process execution rate

Performance measurement

Data flow

Feedback loops

Sub-process bin

Figure 2 A Simple software process dynamics model

In this model, software is developed with an objective to fulfill the given requirements at a certain development rate which is measured in terms of productivity. The requirements are transformed into completed software at the software development rate. The completed software, which is the outcome of the software development process, depends on the performance of the sub-processes such as defect identification and removal (for example, number of defects identified and fixed per day) and test cases execution (for example, test cases executed per person day). Each of the sub-processes consumes inputs and produces the necessary outputs to achieve the intent of the main process output (completed software).

During the course of software development, the outputs of one process become inputs to the other. Efficiencies of individual processes decide the overall efficiency of the main processes. As time progresses, requirements are processed at the software development rate and requirements become developed software, so level (quantity) of requirements decline as level of completed software development activities rises. The software development rate is constrained by several factors: the defect removal rate, testing rate and nominal productivity of people. In order to keep the completed software delivery schedule unchanged, there must be a balanced flow rate between sub-processes in the system.

From the system dynamics perspective, to ensure process equilibrium, levels in the identified bins (requirements, completed software, defects, fixed defects, test cases and executed test cases) must increase or decrease proportionately according to the flow rate of each of the sub-processes. For example, the level of test cases and executed test cases boxes vary according to the testing rate. Additionally, the test cases box level changes with respect to the requirements elicitation rate. Subsequently, the expected level in a completed software box is achieved and maintained along with the flow rate of other sub-processes. Organizations need to study the causes for variations in flow rate and uneven levels to ensure smooth and effective process flow and performance.

3 Process capability versus Process controls

Process stability is ensured by bringing processes under statistical control through execution of the appropriate control actions against special causes. These actions may be for process deviations that have already occurred (corrective actions) or could be for potential deviations predicted based on process behaviour trend from control charts (preventive actions). On the other hand, process capability is a statistical indicator of how well a process is functioning. The increment in process capability indices over a period of time depicts the effectiveness of control taken against common causes responsible for inherent variations. In fact, control actions for common causes are nothing but process improvement actions taken to reduce inherent variations. In statistics, the degree of process variation is measured in terms of standard deviation and capability of a process expressed in terms of process capability indices **Cp** and **Cpk** (**Cp** - assumed process mean is centred and **Cpk** - assumed process mean is not centred) *[Thomas and Paul 2009]*:

$$\mathbf{Cp = (USL - LSL)/\ 6 \times standard\ deviation}$$

$$\mathbf{Cpk = Minimum\ of} \left\{ \mathbf{(USL - Mean)/3 \times standard\ deviation,\quad (Mean - LSL)/3 \times standard\ deviation} \right\}$$

Where, **USL** - Upper Specification Limit of process metric and
LSL - Lower Specification Limit of process metric

Once a process achieves an incremental change in its process capability index, a new set of control limits with a narrower bandwidth are established and future process performance is measured against these limits. Subsequently, the process is monitored against new control limits. With the revised control limits, still a process will have some common causes with a reduced adverse impact on process outputs. Since common causes can't be eliminated completely, variations due to these causes always present in any processes. In order to sustain process stability and improvement results, organizations need to focus on designing and establishing rigorous control actions.

Process improvement initiatives must continue until process quality reaches Six Sigma level *"3.4 Defects Per Million Opportunities" [Basem and Adnan 2010]* or even beyond depending upon the criticality of the process. The following diagram (Figure 3) depicts the association between incremental process capability, process improvement and degree of controls.

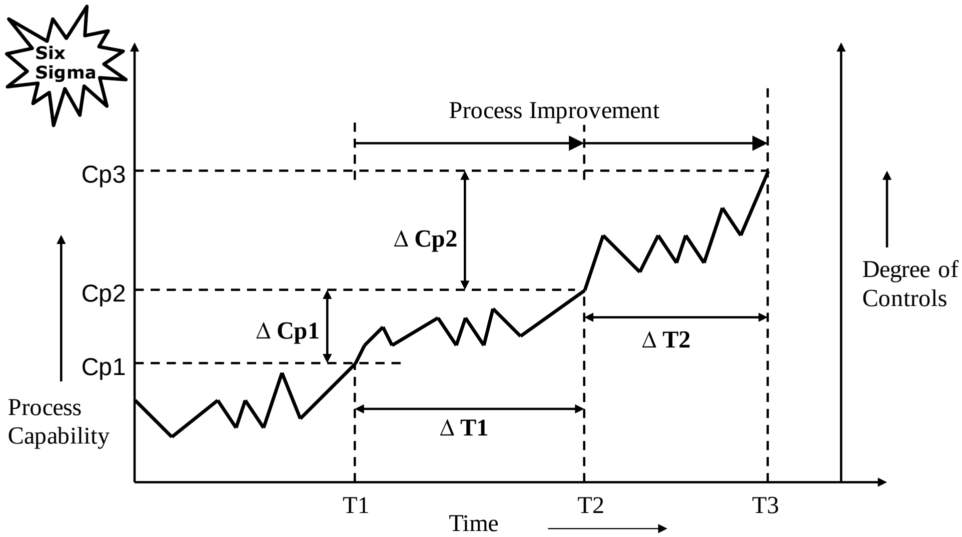


Figure 3 Process: Capability, Improvement and Controls

The relationship between process capability, process control and process improvement can be represented in terms of a time dependent linear function as shown below (for the purpose of clarity only process capability index **Cp** is used, however, **Cp** can be replaced with the other capability index **Cpk**) :

Δ Cp = f (process control × process improvement) × Δ T + inherent process variation

Where,

Δ Cp = Change in process capability over a time period,
(for example, **Δ Cp1** = Cp2 value at T2 − Cp1 value at T1)

Δ T = Change in time period (for example, **ΔT1** = T2 − T1)

Process control: actions to ensure process performance/output between established limits (for example, reviews/checks will control the defect density to remain in established limits).

Process improvement: actions to improve the current level of process performance/output (for example, enhancing the effectiveness in reviews/checks to establish stringent variation limits for defect density).

Inherent process variation: unavoidable process variation which cannot be eliminated or reduced further (for example, variation in competency and skills of the reviewer).

Referring to figure 3 and the above expression, the increment in process capability is a time dependent function of process control and process improvement with some amount of unavoidable process variation. The increment in process capability can be achieved over a period of time only when implemented process improvement actions are coupled with relevant and intensive controls. Process capability is affected by failure of an improvement action to address the causes of variations and/or imposing inadequate process controls. Some amount of inherent process variation is always bound to happen which is not economical and cannot be eliminated or reduced further.

For example, the current (at T1) process capability index (Cp1) for productivity of test case preparation process is calculated as 0.67 (a capability index of 2 is ideal value for a Six Sigma level process). Though the process is stable (statistically under control), a low capability index indicates that the process is not capable enough to produce the outputs within the given specification limits. The process is analyzed and improvements actions are implemented with appropriate controls to improve the process. After four months (at T2) the capability index (Cp2) is calculated as 1.4. The change in capability index Δ **Cp1** (from 0.67 to 1.4) is a function of actions taken for process improvement (e.g., modifying the current test case preparation method) and deployed process control actions (e.g., use of templates) over a period of time Δ**T** (4 months).

The above linear equation is valid as long as the processes are well programmed and futuristic (predictable) in nature. In other words, a process must be stable (under statistical control) and capable to meet process goals along with good control mechanisms in place to mitigate unfavourable conditions.

3.1 Characterizing the process variation:

Characterization of process variation is essential in mitigating the effect of variations on process performance and quality of process outputs. The design and establishment of process controls for variations are driven by the behaviour of the variations and their attributes and characters. Processes behave differently in different circumstances due to various factors and causes. Analysis of process variation patterns and process behaviour provide critical information for initiating process improvement programs and to establish appropriate process control. With the aid of appropriate statistical tools, the characterization of process variation can be done and inferences drawn from the analysis reveals the direction for further investigation to arrest the causes of variation.

3.2 Defining the root causes of variation:

Based on the preliminary inference report and characteristics of variation, the next step is mapping of process variation to the probable causes responsible for the variations. During this effort, care must be taken in identification of causes to ensure that only the relevant causes are mapped to the variations with sufficient analysis and evidences. As the identified probable causes are further evaluated to define the root cause and all proposed actions are based on the root causes, it is very important and necessary to use correct tools and techniques for causal analysis. Many different processes, tools, and techniques (e.g., Failure Mode Effects Analysis, Ishikawa diagrams, Pareto charts) are available for defect/variation causal analysis *[Thomas and Paul 2009]*. All of them have proven to be successful in various situations. While application of these techniques helps gain insight into the sources of problems, a checklist implementation of the techniques alone is not sufficient to ensure accurate identification and effective resolution of “deep” problems. After discovering a set of probable causes for the variation, with the aid of statistical and analytical tools, the exact root causes are identified and evaluated for their significance.

3.3 Controls and improvements:

Actions to eliminate the identified root causes of process variation are proposed in terms of controlling actions and improvement actions. For example, introducing a comprehensive test case review checklist to eliminate the cause ‘ineffective review’ leads to higher defect density in completed software. Controlling actions are nothing but the corrective actions taken to remove the root causes to avoid the recurrence of variations due to the same causes. Improvement actions are actions taken to improve process performance and capability by eliminating the occurrence of relevant potential causes for the variations.

An example of where improvement actions could be used is in the monitoring of software development productivity through a process control chart, in which actions can be taken to avoid the dropping of productivity value below some lower control limit and narrowing width of control limits by reducing the variation. The proposed actions should be evaluated for their significance with respect to the identified root causes through piloting and significance (hypothesis) tests. On deploying both the controlling and improvement actions, there must be a positive improvement trend in process performance and capability.

3.4 Actions for sustaining improvements:

The job of sustaining process improvement results is really a big task as most of the improvements last for a short time due to lack of focus on long term sustaining actions. Planned process improvement actions must address the root causes and appropriate measures for sustenance should be planned and inbuilt as part of improvement actions. A well established measurement and analysis system helps in monitoring and controlling the process performance and also ensures the sustaining of improvement in long run. The sustaining actions could include actions such as imparting training to process performers and owners; periodic review of performance results; adequate monitoring of process controls.

4 SDICC Approach for Process Management

In this section, a structured approach for process management and its components is discussed in line with the expectations for effective process management. This approach consists of five components (abbreviated as SDICC): Strategy; Design; Implementation; Control; and Continuous Improvement. The SDICC process management approach (See Figure 4) provides detailed insight on the requirements for developing a robust process definition and modelling strategy. Each component has its unique contribution and effect on the end-to-end process definition approach.

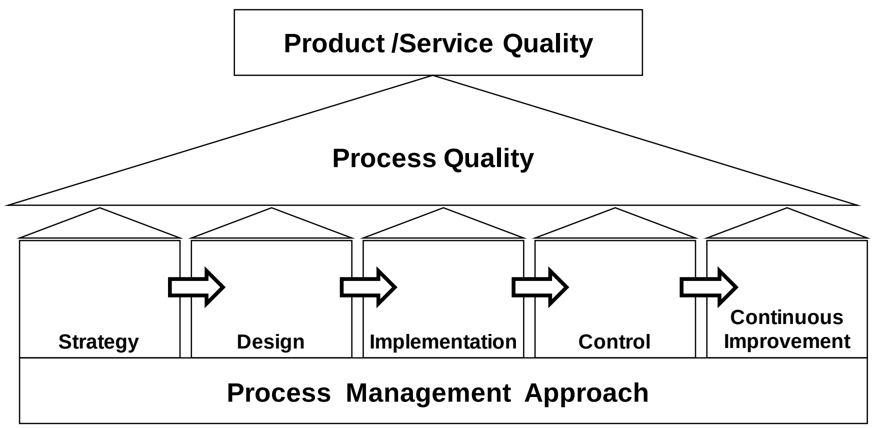


Figure 4 SDICC Approach to Process Management

The above Process management approach provides a structured approach in formulation of processes to ensure consistent product/Service quality. The results of activities within each of the components form inputs to next component. All the components collectively contribute in ensuring the process quality and in achieving the process objectives thereby producing quality product/service. The following paragraphs outline the need and importance of each component in determining the quality of processes and products.

4.1 Strategy

Process strategy is the pattern of decision making in identification, selection and managing of processes so that they will achieve their competitive priorities and build business value through process improvement. The initial information such as customer requirements, product features and organization initiatives should be considered as inputs when formulating process strategy. Process strategy must match with business needs, culture and specific issues of the context. During the course of process strategy, organizations need to consider the quality improvement objectives, current process infrastructure, tools, technology and competent resources. Strategic Analysis Tools like SWOT (Strength, Weakness, Opportunities and Threats), PEST (Political, Economic, Social and Technological) and other decision making tools *[Cornelius 2010]* provide a structured approach in the formulation of process strategy.

4.2 Design

Based on the result of process strategy, prioritized and selected processes are designed to meet process objectives and thereby enable organizations to achieve business and customer needs. The use of a quality function deployment (QFD) tool *[Thomas and Paul 2009]* helps in mapping between specific requirements (what) and methods to achieve them (how). The analysis of possible design failures and their effects is done through the Process Failure Mode and Effect Analysis (PFMEA) tool to ensure robust process design *[Thomas and Paul 2009]*. Practically, the process design involves the identification of process boundaries and dependencies, process and work flow definition and structured documentation. Process definition includes components like scope, purpose, entry criteria, inputs, outputs, tasks involved, roles and responsibilities, monitoring and controlling criteria. Process Definition lists what happens between the start and end points and includes all the activities that transform an input into an output. Quality planning and quality control aspects are built in during process design and definition.

4.3 Implementation

The trigger for process implementation starts once process definition completes. Initial process implementation is piloted on selected areas to ensure adequacy of the process design to enable subsequent process refinement before implementing across the organization. Prior to process implementation, all stakeholders of the process need to be trained on the processes that are planned to be rolled out. A process governance team (which governs the implementation activities) needs to be formed along with an appropriate communication/escalation structure to ensure effective implementation. Process owners and performers should be aware of the purpose, objectives and outcomes of the process along with the relevant measurements to be captured during implementation. All together, process implementation consists of communication, process training and mentoring, tool training, support mechanisms, metrics and infrastructure for continuous improvement in addition to the process definition itself. All associated artefacts must be generated in a timely manner and maintained according to defined guidelines and checklists. While processes are being implemented, the identified process measurements must be captured as per the defined frequency and metrics report generated to track process performance against the targets. Effective process implementation is ensured through use of tools like checklists, guidelines and metrics.

4.4 Control

The primary objective of process control is to track process performance against expected results and maintain steady performance. Appropriate corrective and preventive action needs to be taken in case of process deviation to bring back the process into its normality. The adequacy and degree of controls should be derived considering the stability and capability of the process. A measurements and metrics report should be generated for timely execution of the control actions to achieve the process objectives. Appropriate process control actions identified based on the degree of process deviation, process behaviour and complexity of the problem. Use of typical data analysis techniques/tools like Histograms, Pareto Charts, Scatter diagrams, Cause and effect diagrams and Statistical process control *[Thomas and Paul 2009]* charts help in identifying and selection of required process control actions. The usage and applicability of particular tool depends on the nature of the problem.

4.5 Continuous Improvement

The analysis results from process control provide opportunities for process improvement initiatives. Process control actions can be analyzed further to identify the causes of chronic problems and variations. Improvement opportunities identified with an objective to eliminate the causes or to reduce the effect of causes depending upon nature of the problem. The success in achievement of process improvement objectives lies in adapting and following an appropriate process improvement approach. Continuous process improvements could range from small improvements like Kaizen *[Besterfield 2011]* to break through improvements like Six Sigma. Organizations can choose a suitable process improvement model/approach like Juran Quality Improvement (JQI) *[Mukherjee 2006]*, Six Sigma *[Thomas and Paul*

2009], Lean Six Sigma *[Michael 2002]*, TQM *[Besterfield 2011]*, CMMI *[CMMI-DEV v1.3 2010]*, etc. based on the need and nature of the change or problem.

5 Process Quality Relationship (PQR) Matrix

Quality Management for macro processes is carried out by use of the Juran Trilogy *[Besterfield 2011]*, which basically consists of three stages: quality planning, quality control and quality improvement. These three stages, taken as a whole, form the basis for the entire quality management effort. This approach has been accepted widely and is used in all types of industries (example: Automobile, IT, Banking, Healthcare etc). The Juran Trilogy is essentially concerned with designing products and processes that align with customer needs. In this trilogy, quality is an integral part of the planning, control and improvement activities with a focus on reducing cost of poor quality. During the course of managing the process quality, organizations should consider the process management aspects (discussed in section 4) in developing and framing adequate processes. Though quality and process management activities overlap each other to a large extent while achieving the organizational objectives, the approaches for quality and process management vary with respect to the process execution perspective. For example, the quality improvement component of the quality trilogy provides necessary inputs like quality objectives, customer and market requirements to the process strategy formulation activity. Both process and quality management are an integral part of an organization's operations in achieving and sustaining the product/service quality.

5.1 PQR Matrix interpretation

The following Process-quality relationship matrix (Figure 5) shows the degree of association between process and quality components.

Process Management Components →

Juran Quality Trilogy ↓	Strategy	Design	Impleme-ntation	Control	Continuous improvement
Quality Planning	3	5	3	1	5
Quality Control	1	5	3	5	3
Quality Improvement	5	3	1	3	5

1 Weak 3 Moderate 5 Strong

The numbers represent the degree of association between quality and process components

Figure 5 PQR matrix

The five process management components are indicated along the columns and the Juran Quality trilogy is indicated along the rows. The degree of association between process and quality components has been quantified in terms of Weak, Moderate and Strong (Weak-1, Moderate-3 and Strong-5) to depict how both the process and quality blend together while process modelling. The quantification of relationship is based on the results of impact analysis of each component over the other during process design and execution while achieving the targeted quality.

The PQR matrix reveals the fact that, in totality the components of the quality trilogy across the process management components have equal importance though they have varied one-to-one degrees of association. For example, the relationship scores along the rows for Quality Planning (3+5+3+1+5), Quality Control (1+5+3+5+3) and Quality Improvement (5+3+1+3+5) all total 17. This depicts the need of the attention of process practitioners for considering and ingraining the quality aspects while defining and managing the processes to achieve the set process objectives and quality outputs. The individual relationship value can vary depending on the scale used (current scale is: Weak-1, Moderate-3 and Strong-5) but the relationship attributes (Weak, Moderate and Strong) remains same. With a change in scale, the total score across the rows (current total is 17) changes to a new value but remains constant. This signifies clearly that in spite of varied individual relationship values with process management components, each row of the quality trilogy stages has equal importance to overall quality. The relationship values help process practitioners with a focussed approach in designing value add processes to achieve the best results for the effort.

Considering the relationship scores (columns) for each of the process components, the scores for Process Design and Process Improvement have 13 for each and are highest as compared to others (Process Strategy = 9, Process Implementation=7, Process Control= 9). This indicates that process design and improvements need more focused attention towards quality trilogy elements during process definition and modelling. This analysis clearly reflects how and to what extent the Juran Quality trilogy elements are important in effective formulation of the processes to meet the organizational and business needs. The degree of association between quality and process component pairs is explained in the following section.

5.2 PQR Table

The association of quality and process management evaluated based on their interactions and explained in the below table:

Quality and Process components	Degree of association	Description
Quality Planning and Process Strategy	Moderate	Decisions on process identification and selection are primarily driven by the business needs and high level customer requirements. The requirements are not matured enough for detail quality planning while formulating process strategy.
Quality Planning and Process Design	Strong	Process objectives are formulated and aligned with the quality objectives which are derived from customer and business needs and processes are designed by defining the means to meet those objectives.
Quality Planning and Process implementation	Moderate	The defined processes are implemented and performed to meet the planned process and quality objectives. Process implementation should ensure achievement of these objectives.
Quality Planning and Process Control	Weak	Outcome of process monitoring and control trigger the actions for bringing back the process on track in case of variations but process and quality objectives not change unless there is a change in customer and business needs.
Quality Planning and Process Improvement	Strong	Improvements are initiated to enhance the process maturity level based on performance results and accordingly the process and quality objectives revisited in line with customer and business needs.
Quality Control and Process Strategy	Weak	The feedback on effectiveness of performed processes in achieving the objectives triggers for process improvement initiatives but not revisit of process strategy.
Quality Control and Process Design	Strong	Appropriate process measures for tracking and evaluating the actual process and quality performance are addressed during process design. These measurements trigger the actions against the deficiencies between expected and actual performance.

Quality Control and Process implementation	Moderate	Effectiveness in process implementation is measured in terms of achievement of process and quality objectives. Effective implementation is ensured by taking appropriate corrective and preventive actions.
Quality Control and Process Control	Strong	The identified Process and Quality control measures are complimentary to each other and evaluated against the process and quality objectives during the course of process execution.
Quality Control and Process Improvement	Moderate	Analysis results on outcome of the Quality control activities are the sources for the potential process improvements.
Quality Improvement and Process Strategy	Strong	Identification and initiation of specific improvement projects to enhance the operational efficiency provides inputs for development of new processes and revisit of organization process strategy.
Quality Improvement and Process Design	Moderate	The planned process and quality improvement objectives addressed while process designing along with appropriate performance measures.
Quality Improvement and Process Implementation	Weak	Beneficial change oriented processes implemented through systematic quality improvement plan. A contribution towards quality improvement during process implementation is very low.
Quality Improvement and Process Control	Moderate	The revised process and quality objectives evaluated and controlled through appropriate corrective and preventive actions.
Quality Improvement and Process Improvement	Strong	Both Process and quality improvement are complementary with each other and contribute equally in achieving organization goals. Both shares inputs and outputs with each other.

6 Conclusion

In this paper, the sources and factors responsible for the software process variation were detailed along with their adverse effects on performance of process. The software process dynamics model was discussed extensively and a process dynamics relationship formulated to provide an understanding of the impact of process variation on overall process stability and intermediate/final deliverables.

The relationship between process capability, control and improvement was presented to demonstrate that incremental change in process capability is a time dependent function of process control and process improvement. An approach for characterizing the process variations, defining root causes for variation, establishing process control and improvement actions was described.

Also presented was the SDICC approach for process management. This methodology, based on the Juran quality trilogy model, helps process practitioners design new process and improve existing process performance.

Finally, the relationship between process and quality established through a PQR Matrix demonstrated the importance of Juran quality trilogy components and their association with process management components. The degree of association, along with a description of each association is included in a convenient PQR table.

The author feels that the importance and need for addressing quality factors from process inception to institutionalization, as detailed in this paper, can be useful for a process group involved in process definition and improvement efforts.

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