Validating Requirements Engineering Process Improvements – A Case Study

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Abstract

The quality of the Requirements Engineering (RE) process plays a critical role in successfully developing software systems. Often, in software organizations, RE processes are assessed and improvements are applied to overcome their deficiency. However, such improvements may not yield desired results for two reasons. First, the assessed deficiency may be inaccurate because of ambiguities in measurement. Second, the improvements are not validated to ascertain their correctness to overcome the process deficiency. Therefore, a Requirements Engineering Process Improvement (REPI) exercise may fail to establish its purpose. A major shortfall in validating RE processes is the difficulty in representing process parameters in some cognitive form. We address this issue with an REPI framework that has both measurement and visual validation properties. The REPI validation method presented is empirically tested based on a case study in a large software organization. The results are promising towards considering this REPI validation method in practice by organizations.

Keywords: RE Process Quality, Quality Measures, RE Process Improvement, RE Process Improvement Validation, RE process visualization

1. Introduction

Requirements Engineering (RE) involves activities in discovering, verifying, documenting and managing a set of requirements for a software system [1]. Research has established that the quality of RE influences the quality of requirements and in turn software quality [1-5]. It has been empirically proven that there is a distinct relationship between the quality of requirements and their influence on [1, 4, 6]:

1. Density of defects in software, particularly in live use.

2. Rework in almost all phases of the Software Development Life Cycle (SDLC).

Failure to detect and correct defects in software before it is deployed, and failure to identify defective requirements (poor quality requirements that are found to be inconsistent, incomplete or ambiguous) and correct them early on can result in project cancellations and failures [3, 7, 8]. Thus, RE plays a critical role in developing and maintaining software. However RE does not always produce desired results in the form of good quality requirements. Therefore RE processes are used to guide requirements engineers to elicit, analyze, validate, document and manage requirements [9].

RE processes are part of RE and they define specifically how RE should be conducted [10, 11]. There are many types of RE processes described by research, and in use in organizations that develop software [9-13]. The variation is mainly in the categorization of RE activities, and in the work products and deliverables of RE. However, most RE processes are complex and ambiguous, thus making their cognition difficult. This calls for visually representing RE processes using simple visualization techniques.

RE processes are improved when they fail to meet their desired purpose. Often improvement is applied to RE processes without measuring their deficiency, thus rendering the applied improvement ineffective. It is important to measure the process and apply improvement pinpointed against measured deficiency because of the difficulty involved in representing an RE process against measuring scales. Thus visualization of process measurement becomes crucial to achieve Requirements Engineering Process Improvement (REPI) that has a positive influence on an RE process.

Unfortunately, failure of an RE process to produce desired results is usually not evident until software is put to formal testing where defects (software not working as intended) are recorded. At the same time, research has proved that poor RE can increase the

defect density in every subsequent phase of the SDLC [14]. Figure 1 indicates typical life cycle defects against Capability Maturity Model (CMM) levels 1-3.
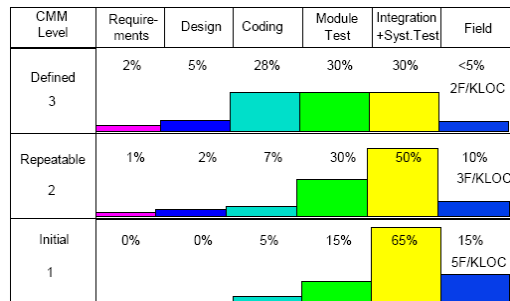
CMM Level	Require-ments	Design	Coding	Module Test	Integration +Syst.Test	Field
Defined 3	2%	5%	28%	30%	30%	<5% 2F/KLOC
Repeatable 2	1%	2%	7%	30%	50%	10% 3F/KLOC
Initial 1	0%	0%	5%	15%	65%	15% 5F/KLOC

Figure 1 Typical life cycle defects against CMM levels 1-3 [14]

The project measurement data, such as the one indicated in figure 1 does not guide REPI. This is because, it is difficult to analyze what is the exact problem (such as, the number of defects and how many of them are severe defects) created by a poor RE to each phase of the SDLC. Further, defects data such as the above is usually available too late in large projects that span a significant calendar time to provide immediate benefit. Thus, it is important to:

1. Measure an RE process early on, during the RE itself [15].
2. Validate the improvements to check if the RE process changes are correct, preferably using visualization to simplify the complexity of RE processes.
3. Deploy improvements, especially those that address the measured and prioritized deficiency [16, 17].

Usually, in reality, the processes are assessed, improved, deployed and improvements are verified to see if they produce the desired results [18-21]. The risk associated with this approach is that the intended process improvements may be mere process changes, sometimes, with a negative effect worsening the existing situation. This defeats the purpose of REPI, forcing an REPI to become a discontinuous exercise with no establishment of appropriate logical stages.

Validating REPI will guarantee improvement even before the improved process is deployed. Further, visualization of the validated REPI can increase the level of understanding of the REPI exercise amongst senior staff. At the lower levels, such visualization provides opportunity to increase the process knowledge

levels amongst process users. In general, visualization of REPI can make an RE process more predictable and can prevent the common recall of the new process rollout.

It is difficult to establish REPI validation before the improved process is deployed. This is because there is no ideal RE process that can be used for comparison to establish the validity of REPI [17]. Perhaps for the same reason, there are no research models, methods or techniques describing REPI validation. We address this problem by:

- Attributing validation property as a component of the REPI framework that is central to this empirical research [17].
- Using a visual model for REPI validation.

Visualization of REPI validation helps to manage the complexity of RE processes, and conveys rich information against RE process dimensions. The validation approach described here is tested in a large multi national software development organization that develops large and complex high assurance systems.

2. REPI Validation Decision

We define REPI validation as a term used to indicate that an improved process (improved process does not mean that it has been deployed) has been subjected to such scrutiny that the result of the REPI is practically guaranteed to produce positive results when deployed. REPI process validation involves establishing by objective evidence that an improved RE process consistently produces a result or product (good quality requirements) that meets its predetermined needs.

Any software process validation involves the following steps [22-24] to ensure if we:

1. Understand what the process is supposed to do.
2. Understand what the process context is (input, output and users).
3. Understand what the process users' needs are.
4. Have arrived at the correct process (by validation and verification).

The difficulty involved in applying the above steps to an RE processes is high because most RE processes are complex and ambiguous [10].

The first step in RE process validation is to determine if verifying (defined as measuring a process after deploying) an improved RE process is sufficient. Verification, although easy has a trade-off of efforts

involved in managing risks associated with an untested process put into live use. As against this, validation, when performed correctly can guarantee that improved RE process works as intended, even before the process is deployed.

The model illustrated in figure 2 assists in determining whether or not a process should be validated.
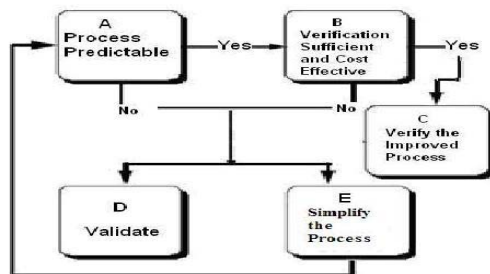

Figure 2. RE Process validation decision tree

An improved RE process should have a specification describing both the process dimensions and the output desired. We should consider whether the process is predictable by subsequent monitoring or measurement (refer to figure 2 part A). If the answer is positive, then the consideration should be made as to whether or not verification alone is sufficient to eliminate unacceptable risk and whether it is a cost effective solution (part B). If yes, the output should be verified and the process should be appropriately controlled (part C). If the output of the process is not verifiable then the decision should be to validate the process (part D). Alternatively, it may become apparent that the process should be redesigned by reducing complexity (part E). The risk or cost may also be reduced by redesigning the RE process to a point where simple verification is an acceptable decision (part E).

We next examine how to focus on validation points and qualify an improved RE process for validation.

3. Establishing Process Validation Points and Qualifications

Process validation points determine where validation/verification has to be rigorous or not. Research classifies RE sub-processes as Elicitation, Analysis, Documentation, Validation and Management of requirements [1, 4, 6]. Each of the above can be broadly categorized into processes that: (1) should be validated, (2) may be satisfactorily covered by verification, and into processes which may either be (3) verified or validated as to whether they meet organizational goals (for example, quality certification needs). An example of a list with 1 to 3 numbers (Low Importance to High Importance) representing the process focus areas as described above is: Elicitation – 2, Analysis – 1, Verification and Validation – 1, Documentation – 3, Management – 3.

Having set the process focus areas for validation, the next step is to qualify an RE process:

- Deployment qualification (DQ): In this phase, questions should be raised to check if the improved RE process deploys correctly? Examples of important considerations are deployment conditions (e.g. rollback decisions), environmental conditions (eg. what other processes in the SDLC will be impacted) schedules (e.g. do we have enough time to deploy), documentation (e.g. REPI rationale and deployment instructions) and training (e.g. usability changes).
- Operational qualification (OQ): In this phase the REPI process parameters should be challenged to assure that they will result in requirements that meet all defined qualities. The considerations include the following five process dimensions [15]:

  Dim 1. Time and Effort allocation
  Dim 2. Artifacts produced by RE
  Dim 3. RE Activities
  Dim 4. Disciplines and Automation
  Dim 5. Roles

  Potential failure modes, action levels and worst-case conditions (such as, Failure Mode and Effects Analysis and Fault Tree Analysis [25]) are used to establish qualifications.
- Performance qualification (PQ): In this phase, the key objective is to demonstrate that the process will consistently produce acceptable results. Considerations include:

  1. Process parameters established in OQ.
  2. Acceptability of the requirements based on defined requirements quality.
  3. Assurance of process capability as established in OQ.
  4. Process reusability and long term process stability.

Challenges to the process should simulate conditions that will be encountered during actual live use of the process. Challenges should include the range

of conditions as defined by the various action levels allowed in written standard operating procedures as established in OQ. The challenges should be repeated enough times to ensure that the results are meaningful and consistent.

4. Improved RE Process Validation Approach

In this section we first differentiate between RE process validation and RE product validation, and then describe an approach to validate an improved RE process to determine its capability.

4.1. RE Process versus RE Product (Requirements) Validation

Validation of a process is based on the comparisons of accumulated historical process data based on the 5 process dimensions mentioned in section 3 [15], and what is intended to be achieved by the improved RE process. This is achieved with four-steps:

1. Establishing exactly how each of the process parameters contribute to the RE strategy that is aligned against the organizational goals.
2. Ranking the values of dimensions against a 5-dimensional scale of the historical data.
3. Comparing the improved RE process values against each of the dimensions with the historical map and with the one that has been chosen as a goal.
4. Revalidating the process, only if necessary.

The above validation establishes the capability of a process. The same can be assessed later on (after the process develops requirements in live use) by examining the requirements.

4.2. RE Process Dimensions and Parameters

Establishing exactly how each of the process dimensions mentioned in section 3 contributes to the organizational goals. This involves a clear mapping of the five dimensions Dim 1 to Dim 5 mentioned in section 3 that delineates the organizational goals. Two goals that are usually common to software organizations are optimizing the SDLC schedules by reducing rework (which is mainly contributed by poor quality requirements) and reducing defects in software after it is released for live use in business (the root cause is usually poor quality requirements). Figure 3 indicates this relationship.
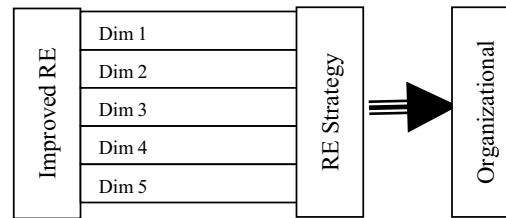

Figure 3. RE Process dimensions influencing organizational goals

Each of the dimensions can have numerous parameters that are atomic in nature and take binary values of 'Yes' or 'No' (Example – a parameter under Dimension 4 is "Are requirements managed using an RE tool – [Yes/No]"). The level of detail required for an analysis of various parameters under each of these dimensions is directly related to the intended use of the RE process and the availability of information. A less detailed analysis may be sufficient when the RE process is used for a non-critical or small business application. Situations that require a more detailed analysis of various parameters may include those in which little existing information is available and the organization intends to develop large and complex software systems.

The information related to RE process dimensions forms the evidence needed for validation.

4.3. Ranking the Values of Dimensions

Specific information of the improved RE process with respect to dimensions and parameters is collected using REPI rationale, and the performance reports of the earlier processes.

Figure 4 shows the assessment of where improved REPI currently is, with respect to the five key axes in the graphical representation of the five dimensions [26]. We are reusing the measurement representation of the five axes in the polar graph used by Cockburn to distinguish between the lower values (toward the centre of the graph) and higher values (toward the periphery) [27].
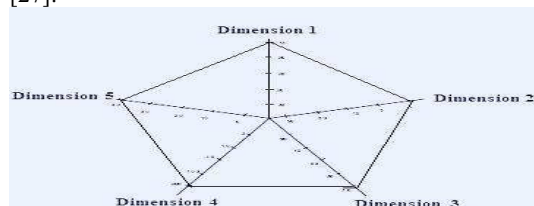

Figure 4. RE Process assessment against the five process dimensions

Obviously, the larger the pentagon is, the better is the process. Further, uniformity of process capability is reflected by the shape of the pentagon. The pentagon will map to be distorted for a non-uniform process that measures well in one dimension and poorly in the other. However, the most important factor that makes this method to work is carefully providing the correct gradations of scales starting from the origin. Any major deviation to the desired process can be further managed by risk management to address the variation.

4.4. Comparing the Improved RE Process Values against Previous Process and Ideal Process

RE process capability measurement can sometimes fall short of the desired level. As indicated in figure 4, if the pentagon is regular in shape, then there are issues related to all dimensions meeting the organizational goals. If the pentagon is irregular (i.e. stretched in some corners), this indicates that only few dimensions need further improvement, for which, an organization needs to develop an incremental strategy to take the process from the current situation to the one that has been chosen as a goal. For example, an organization may solve the problems with automating the process and this may provide significant gain, even though manual processes have been enacted and conformed to thoroughly.

Trends in the process should be monitored to ensure that the process remains within the established parameters. When measurement demonstrates a negative trend, the cause should be investigated, corrective action should be taken and revalidation considered.

4.5. Revalidation

Any evolutions (i.e. natural changes, such as creating new work products) in the process and/or product specifications (for example, changes to the requirements quality checklist) should be evaluated to determine if the effects of the changes are forcing current validation to become irrelevant or invalid. Therefore, periodic revalidations are to be considered to establish a state of control. Other reasons for revalidation are the negative trends of data and process context changes. Revalidation rationale should be clearly established with circumstances explained with the support of historical process data. We propose that revalidation need not be as extended as that of the initial validation, if the situation does not require that all aspects of the original validation be repeated. For

instance, if a technology is introduced, for a validated process, obviously the DQ portion of the validation needs to be repeated. Since most of the OQ aspects are already established, some elements of PQ may need to be repeated, depending on the impact of the new technology. Another example could be if there is a change to Pre-RE (such as changes to process that generate a marketing requirements document) and the impact of that change on the RE process to be considered. Parts of DQ and PQ might need to be redone, without which the interaction between the new entry criteria and the process may not be fully understood.

5. Statistics and Process Validation

Each measurement of an RE process can differ at least by a small degree from other measurements. These differences, no matter how small, are referred to as variations. Variation can be characterized by measuring a sample of the measurement and drawing a histogram. For example, the following are the results of an REPI validation: 98.7 99.3 100.4 97.6 101.4 102.0 100.2 96.4 103.4 102.0 98.0 100.5.

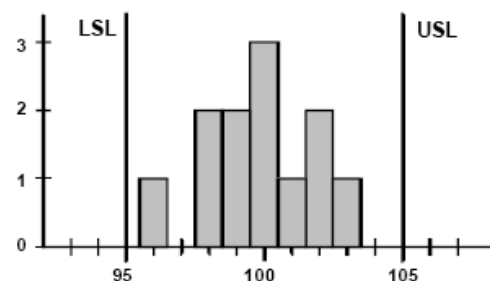A histogram of this data is shown in figure 5. The width of the histogram represents the variation.

Figure 5. Histogram of example data

Of special interest are whether the histogram is properly centered and whether the histogram is narrow enough to easily fit within the desired limits. The width of the histogram is estimated by calculating either the range or standard deviation. The range of the above readings is 7.0 and the standard deviation is 2.06. The standard deviation represents the typical distance a unit is from the average. Approximately half of the units are within ±1 standard deviation of the average and about half of the units are more than one standard deviation away from the average. On the other hand, the range represents an interval containing all the units. The

range is typically 3 to 6 times the standard deviation [28].

Frequently, histograms take on a bell-shaped appearance that is referred to as the normal curve as shown in figure 6. For the normal curve, 99.73% of the units fall within ± 3 standard deviations of the average.
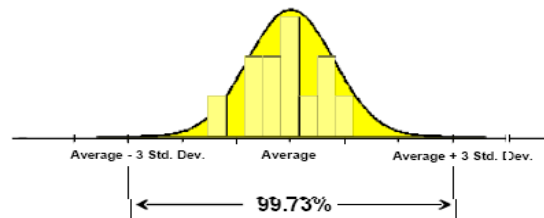

Figure 6. Normal curve applied to histogram

For measurable characteristics like Dim 1, Dim 2, Dim 3, etc., optimization of the average may mean to stabilize the process. In all dimensions, variation reduction is also required to ensure that the improved RE process is within the specification (REPI recommendations associated with rationale [29]).

Reducing variation requires the achievement of stable and capable processes across time. Figure 7 shows stable and unstable processes.
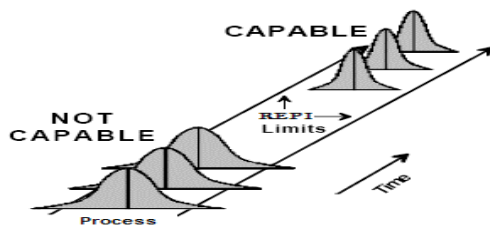

Figure 7. Stable and unstable RE processes

The unstable RE process in figure 7 is constantly changing with its average shifting up and down. The total variation increases due to the shifting. Stable processes produce a consistent level of performance. If the total variation is reduced, the process is more predictable. However, stability is not the only thing required. Once a consistent performance has been achieved, the remaining variation must be made to safely fit within the upper and lower specification limits. Such an improved RE process is then said to be both stable and capable.

6. Process Improvement Based on the Capability Determination

While process validation evaluates the ability of an RE process to consistently produce good products (i.e. good quality requirements), the validation by itself does not assist in providing help to achieve such results. Reducing the variation and achieving a stable RE process requires the use of numerous variation reduction tools. For instance, a variation of the process output is caused by the variation of the inputs. The obvious approach to reduce variation is to tighten tolerances on the dimensions and parameters used for analysis and check how process fairs against them. This can be achieved only by reducing the complexity of the validation by using simple visualization techniques.

In the next section, we illustrate a case study snapshot to demonstrate the validation mechanism used in a large software development organization that develops high assurance systems. The purpose of the complete case study was to mature an RE process beyond Capability Maturity Model (CMM) level 3 to match with the other SDLC process levels. Therefore, RE process measurement and validation was central to the case study.

7. A Case Study Snapshot to Illustrate the Success of this Method

Section 7.1 introduces the organization and its RE culture, followed by the REPI context for the validation exercise. Keeping the size restriction of this paper in context, section 7.2 describes briefly the real life validation exercise. The snapshot acts only as an example and interested readers can obtain the complete descriptive case study from us.

7.1. Case Study Introduction

Organization Z1 (unspecified for the purpose of confidentially) established RE as part of the CMM level 3 certified quality program. The purpose of Z1's RE process is to establish complete and consistent requirements. The main focus on RE is the requirements review process for validating (e.g. to answer questions like "Do we need this requirement?") and verifying (e.g. to answer questions like "Is this requirement correct?") requirements. The RE process is manual and various templates stored on the network assist process users to comply with the process.

This case study was initiated as part of the main research, which is to establish empirical evidence for

the success of the REPI research framework. REPI validation is one of the components of the framework. The agreed objective of this study was to carry out critical assessment of the current RE process, identify the strengths as well as opportunities for improvement, if any, and provide validated recommendations in the first phase. In the second phase, the objective was to improve the RE process by addressing the process problems based on a priority. The RE in this organization did not have intermediate milestones since RE sub-processes were not well-defined.

We examined the RE processes using the following dimensions described in section 3 [15, 30]:

Dim 1. Time and Effort allocation: How RE is arranged over time and how RE staffing effort compares to the SDLC effort.

Dim 2. Artifacts produced by RE: Various deliverables like data, effects, results, documents, etc. resulting from RE process usage.

Dim 3. RE Activities: What activities produce artifacts including the requirements specification.

Dim 4. Disciplines and Automation: Delineate major areas of concern in the SDLC that can influence RE, and technology and tools usage to manage RE.

Dim 5. Roles: Various roles in RE and differences between them.

The main sources of information used in the analysis against the above dimensions are Z1's business plans, information exchange between Z1 and the software stakeholders, process documentation, requirements specification template with samples, review results, project management and test management plans, and RE literature from the public domain. Information gathering methods were: one-to-one discussions with the SDLC staff and management; observations of the specification review process; performing real life internal audits and applying questionnaires.

At the end of Phase I, the documents submitted to Z1 were: some general observations (positives as well as negatives); some specific observations (negatives); and a list of poor quality attributes in requirements across products and releases (negatives). This information was verified for correctness before submission by: (1) a peer review and (2) running a high-level questionnaire amongst managers and a detailed survey amongst the SDLC staff, both in anonymity. The questionnaires obtained somewhat accurate and correct information. This was subsequently verified by reapplying the same questionnaire for a second time.

Upon the acknowledgment by Z1 that the documented RE process problems existed, the suggested recommendations were applied to the RE process based on a priority arrived as part of this research [15]. However, improved RE process was not deployed until the improvements were validated and proved to achieve results. On obtaining successful results in the validation program, the improved REPI is currently being deployed in a phased manner. The funding allocated for the entire REPI was AUD75,000 with +10% contingency.

The requirements quality was examined across 5 large and complex projects and consistent poor quality was observed across all 5 projects using a requirements quality checklist as indicated in table 1.

Table 1. Requirements quality checklist

Requirements quality	Importance
Succinct	High
Atomic with a Requirement ID	High
Traceable to other requirement	High
Traceable to user goals	High
Business context included	High
Glossary – clarity and completeness	Low
Limits not stretched to system design	Medium
Controlled changes	High
Testability	Medium
Rationale	Medium
Effort estimation accuracy	High
Relevance	High
Achievable	High

Examination of the RE process indicated some RE process problems that had the following impact:

1. The process gaps were affecting the RE phase driving RE effort more than estimated (e.g. 101 issues logged as a result of a single specification review meeting).
2. The process gaps were causing confusion in the meaning of "change", hence changes were being introduced without getting customers commitment to those changes (requirements added and excluded without a formal approval mechanism).
3. The process gaps were creating rework in the SDLC, challenging the correctness of the planning phase of the SDLC (all who answered the questionnaire acknowledged schedule overruns as a result of poor quality requirements). The rework was a result of developers fixing faulty design and code, both sourced by poor quality requirements, and

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testers having to re-test the modules and having to test the defects fixed and cancelled (because the desired functionality of the system was not known to the testers).

The process problems were examined under three categories: RE, Change Management (CM) and Risk Management (RM), as CM and RM influence RE quality [17]. The specific process problems that influenced the quality are stated in [15]. The process gaps were prioritized and eliminated in the improved RE process (but not deployed to live use). This formed the entry criteria to the REPI validation exercise.

7.2. REPI Validation

This section presents a brief overview of the validation mechanism that was used in the case study. The mechanism described here should not be considered a complete model for an REPI. However, this can be used as an example and may be modified according to specific quality management systems, documentation needs, SDLC procedures and the cultures of the organizations that use this mechanism.

The first step in this exercise was to develop a validation plan that had the following details:

- General information: Title of validation, Process name, Product and release names (if specific) and Process change control number
- Validation Goals: Objective (why is validation required?), Reference artifacts, Validation plan (DQ, OQ and PQ descriptions as described in section 3)
- Measurement information: What process dimensions are measured? and the rationale behind the choices (as described in section 3)
- Revalidation plan: Where is this document? when will this be updated? and what historical data is maintained? (as described in section 4.5)

The second step was to perform actual validation of the RE process under the three qualifiers DQ, OQ and PQ. DQ example results are shown in table 2.

Table 2. DQ checklist data

#	Need	Source	Conforms?
1	Affected processes assessed	CM and RM	Conforms
2	Process rollback described	Section 2.3 of 2N 222.doc	Conforms
3	REPI rationale made persistent	Feasibility training proof in email	Conforms
4	Deployment schedules determined	REPI V2.0.mpp	Conforms
5	Process change control is established	CM 2.01.doc	Conforms
6	Revised RE process training plan	TRG_CHGP3 .0.1.pdf	Does not conform

The first 5 DQ needs in table 2 are satisfied to be further examined for OQ. We decided that Need 6 is not fit for further analysis, hence we decided to iterate the analysis of why this important need was not conformed to. To determine OQ of the first 5 needs, we mapped the improved RE process to figure 3 as shown in figure 8. The mapping resulted in an irregular inner pentagon that indicated process problems compared to the ideal process represented by the outer regular pentagon.
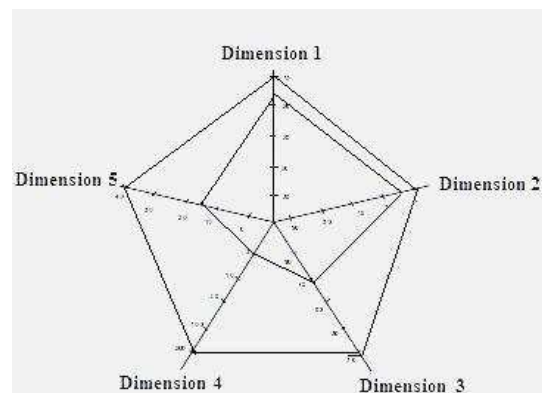

Figure 8. Mapping of the improved RE process dimensions to figure 4.

Appendix A gives an example of how the scores in figure 8 are computed. The deviation from ideal

process is obvious against these organizational goals: 1. Reduced defects delivered to customer, 2. Optimizing the SDLC schedules, 3. Reduced frustrating rework in the SDLC, 4. Reduced release recalls, and 5. Reduced estimation errors. Thus, it was proved that the REPI was not really producing all of the intended results. The problems were classified into pure RE problems and those that influence RE such as CM and RM, which has been researched and discussed earlier [15, 17].

Obviously, figure 8 indicates that Dim 3, Dim 4, Dim 5 did not achieve the desired results in isolation or while being integrated with related processes – CM and RM. The summary snapshot is shown in table 3.

Table 3. OQ checklist data

Problem	Description	Addressed
RE1	RE budget is incorrect	Yes
:	:	:
RE7	Establishing RE sub phases clearly	No
CM1	Change in RE is not well-defined	Yes
:	:	:
CM4	Change control on artifacts templates not established	No
RM1	Risks related to under-consumption of RE effort not managed	No
:	:	:
RM3	Risks related to RE staff being primarily programmers and not analysts not analyzed	Yes

After being aware of the above situation, Z1 had two choices:

1. To improve RE further to address the problems exposed in the above analysis.
2. To deploy the improved process after analyzing risks associated with not addressing obvious problems before the deployment.

Based on these results it was apparent that the process deviation from the desired state was obvious. An additional 4 rounds (RE for 4 different products) of process parameter qualifications were done. The results indicated a variance of 0.6 in a scale of 0 to 1. This itself was enough evidence that REPI was not going to work as intended in live use. We recorded the issues in the form of a single page summary table and decided to reapply the improvements based on the issues. The issues log had details like Product name,

Reviewer, Review Date, Reference, Issue description, Category and Severity of issues.

PQ results in similar terms (only at the level of dimensions) were established for the actual process in live use. The results of the improved and validated process indicated that the process was stable and capable. The target of the desired result was very close compared to the improved process at the time of validation. Since these were at acceptable levels, we did not make any further root cause analysis and we did not apply adjustments to the validated REPI in live use. The issues in this report consisted of the comparisons of validated results with that of the process performance in live use, revision status of validation plan that was initially written, and the communication protocol set amongst process users [30].

We finally signed a statement with broad content as: "We have reviewed the improved RE process Version no. - X; the IQ, OQ and PQ reports. All REPI needs have been met and the process is now validated."

Revalidation at a high-level was applied as RE process gaps were closed after each cycle of validation, and this was conducted as an informal exercise.

8. Conclusion

REPI validation is critical to improving an RE process to ensure that the improvements actually achieve desired results when deployed in live use. However, it has not attracted much research attention. A simple visualization technique to validate REPI has been achieved in this paper by reusing validation and visualization mechanisms from other disciplines. The method has been tested in a large software organization and the validation method has been instrumental in establishing RE as a key process area for continuous improvement, which was otherwise scarcely improved in staged steps. The next step is obviously to replicate this method on REPI of another large organization that develops complex systems.

Appendix A – Calculation of Scores against Process Dimensions

This appendix gives a brief overview of how the scores were determined to arrive at process mapping in figure 8. Because of the document restrictions, the process parameters are not described here. However, a comprehensive list can be obtained from [15]. Table 4 gives the scores for a particular version of RE (version V 1.3.5) in organization Z1. True scores are those that are satisfactory parameters and False scores are those that are not satisfactory parameters.

Table 4. RE process scores for RE in Z1

Dimension	Number of Parameters analyzed	True	False	Percentage of True scores
Dim 1	20	18	2	90%
Dim 2	9	8	1	89%
Dim 3	25	10	15	40%
Dim 4	4	1	3	25%
Dim 5	5	2	3	40%

The True scores are considered for mapping. False scores are analyzed for deployment based on standard RM process of Z1. True scores are scaled using percentage calculations and mapped to the dimensions axes to obtain the pentagon shown in figure 8.

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