Predicting test effectiveness using performance models in Life Science IT projects

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Abstract – Testing plays an important role in any project irrespective of the domain. The ability to test right before it reaches the intended customer matters. Test effectiveness is an important metric that tracks the ability of the testing team. The efficiency of a tester to cover all aspects of testing and ensuring 100% coverage determines the quality of the product. There could be number of factors that influence the test effectiveness. Organizations rely on the quality assurance team to strategize and plan the testing phase. Past experience in handling similar testing projects matter. Shifting left, the opportunity to be in pro-active mode helps to improve the efficiency. Predictive process performance models can be built for test effectiveness. This paper illustrates the process performance model to predict test effectiveness based on data from life science project in an organization.
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1. Introduction to Test effectivess

Test effectiveness or bug finding effectiveness of the test set can be found by dividing the number of bugs found during testing divided by the number of bugs found in the product. It is a key metric that IT quality assurance team will track for every release or change request that the team works on. It primarily covers the aspects around how the customer requirements and specifications are satisfied based on the effort spent in developing the system. Identifying the number of defects during test execution in specific phase of the project is critical. Domain experience is an important factor to understand the application or system. This will help to build the appropriate test strategy.

Test effectiveness is a quality metric meaning how good is the product during testing. Test effectiveness is focused on the product quality and process quality as it is directly related to defects identified by the customer. It is the effectiveness to find the defects during core test execution across the different rounds of testing. It is applicable for any type of testing performed as part of the project life cycle. Each organization would interpret test effectiveness in different context. Some might include only production defects, some might include only accepted defects, and some might include rejected defects as well. The organizational definition should clearly articulate the operational definition and it should be explicitly mentioned in the statement of work.

2. Process Performance Models in Organizations

Process Performance Models (PPM) is probabilistic, statistical and simulative in nature. It can predict interim and final outcome, it is a proactive measure of tracking the end goal instead of a reactive one. It can model the variation of factor and help us understand the predicted range or the variation of its outcomes. Mid-course correction can be made to achieve desired outcome. Interestingly, PPMs enable "What-if" analysis for project planning, dynamic re-planning and problem resolution during project execution. We can run "what if" exercises holding one or more values constant. We can see the effect of tradeoffs between schedule, effort, defects, staff and functionality

Software Engineering Institutes Capability Maturity Model

Integrated (CMMI) standard recommends five maturity levels. Levels 4 & 5 are defined as the high maturity levels. Process performance models are the base for high maturity. Quantitative project management is referred to in high maturity levels. Though the focus on metrics starts at Level 2 and Level 3 itself, statistical and quantitative management is covered in Level 4 & Level 5. Strong metrics handbook across the different work types is a must for organizations. The ability to capture the metrics and analysis the metrics is the base to move to high maturity. Managing a project quantitatively involves predicting project outcomes bases on the project data.

PPB is the base for process performance model (PPM). The PPM describes the relationships among attributes of a process and its work products. It is used to predict a value of a critical outcome that cannot be measured until later in the project's life. For example, predicting the number of delivered defects. A high level business objective (Y) would have multiple next level business objective (y's). In turn, these small (y's) would have project level measurement objectives. These small (y's) are further drilled down to high level process measures (X).

In any testing project, the test strategy and test plan are the most important steps. Based on the project context there could be exclusive test strategy for functional testing and integration testing. At each phase, the test plan and test design plays an important role. The way the test scenarios are thought through and the test cases are written matter. The domain experience of the team is critical. Most of the large customers outsource development part to a vendor and testing to another vendor. This would ensure the transparency in findings defects. Using PPMs, if it is a testing project, and test effectiveness has to be predicted, then test case execution process would critically influence test effectiveness. Manager will have to look at past data to see the various parameters than influence test case review. For example it could be test conditions or test scenarios or combination of both. Upper and lower specification limits for each of these have to be arrived.

Typically process performance model are established to manage the Project Objective. PPM's are used by Project manager during planning phase and throughout Project management life cycle. PPM helps in proactively identifying risks in achieving project objective and identifying the action plan. Before implementing corrective action, Project Managers use PPM to see the impact on the objective. If there are no risks, we go ahead and implement corrective action.PPM is used to check the implementation effectiveness of Corrective action. The organization uses PPM and PPB for estimating, analyzing, and predicting the process performance associated with the processes in the organization defined process and identify areas that require improvements and innovations.

3. VARIABLES ASSOCIATED IN PREDICTION MODEL

Based on brain storming session with the project team in the organization the different parameters that influence test effectiveness in a testing project were looked at. The team shortlisted following factors to start with, domain experience, technical experience, test effectiveness, defects identified during testing phase, testing review efficiency and usage of tools. Operational definitions for these parameters were baselined and data was collected from projects in a particular account against these parameters. Linear regression was performed against the data to find out which are the key variables that influences the test effectiveness. After many trial and error methods the below three variables were established as the x factors.

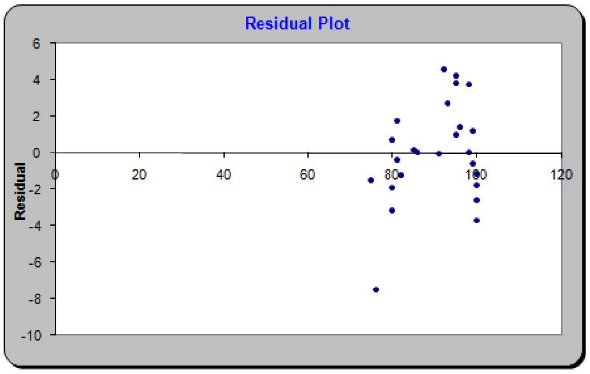
1. Y – Test effectiveness – Total number of defects identified by the testing team / (Total number of defects identified by the testing team + total number of defects indentified by the customer)
2. X1 – Life Science Domain experience – Average life science domain experience of the team, in person months
3. X3 – TCEDD – Test Case Execution Defect Density - Defects attributed to test execution, identified during test execution review against effort spent for test case execution.

4. TEST EFFECTIVENESS – REGRESSION EQUATION

The project data collated for the x and y factors are as shown in the Table 3.1. Data points from 25 projects in an organization were collected and considered for analysis. Projects factored in were similar in nature.

Y	X1	X3
Test Effectiveness (%)	Life Science Domain Experience (in months)	Test Case Execution Defect Density
95	30	0.620
99	40	0.950
80	10	0.110
81	15	0.150
96	35	0.800
99	45	0.950
85	22	0.250
91	34	0.450
100	50	0.990
100	52	1.000
95	31	0.890
86	25	0.250
81	10	0.110
75	5	0.005
100	48	1.000
98	34	0.800
80	16	0.300
95	32	0.500
92	24	0.450
100	55	1.000
93	32	0.450
98	42	0.890
76	13	0.450
82	23	0.030
80	19	0.050

Table 3.1 – Project data values



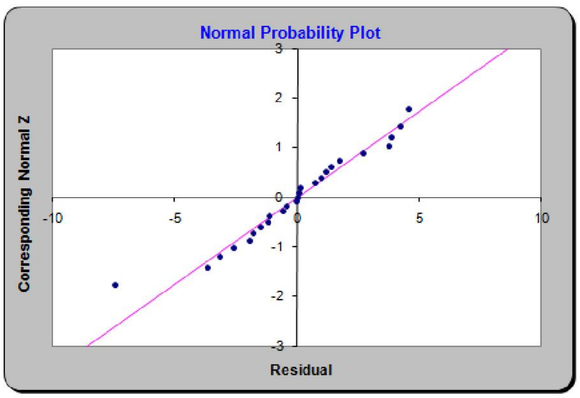


Figure 3.1 – Residual Plot

Mirror pattern is not found in Figure 3.1, Residual Plot and hence no heteroscedasticity is found. The normal probability plot is approximately linear. This would indicate that the normality assumption for the errors has not been violated.

The p value for test case execution defect density is 0.01 which is < 0.05, also the domain experience p value is 0.0009 which is also < 0.05, null hypothesis is not valid, which means the variables selected have an impact to test effectiveness.

Table 3.2 – Regression Equation

Intercept	Domain Experience (in months)	Test Case Execution Defect Density
74.63	0.3595	9.2573

As shown in Table 3.2, domain experience has a positive influence on test effectiveness. As the team's domain experience increases the test effectiveness increases. The influence of Test Case Execution Defect Density is positive. This means that when the values of Test Case Execution Defect Density are low the test effectiveness will be low and vice versa. The more the defects are identified the higher the test effectiveness.

5. TEST EFFECTIVENESS – COMPONENTS OF PREDICTION MODEL

Based on project data analyzed it is evident that test effectiveness is critically influenced by test case execution sub process and domain experience. Life science domain knowledge is referred to as domain experience. Organization base measurement group will provide the baseline data for these metrics. For test case execution sub process, the number of rounds of testing is considered as the parameter. First, second and third round of testing are the parameters factored. Metrics Council group will share the baseline values for these combinations. Baseline values will include lower specification limit (LSL), goal and upper specification limit (USL). The upper and lower specification limits for domain experience and test effectiveness defect density will be provided by the metrics group. Project team needs to choose the process that they would be following for test execution sub process. Project team will have to factor the average domain experience in the team. Based on the composition of sub process, project goal for TCEDD would be calculated. It is also important for the project team to justify why they have gone with a particular sub process and the rationale. Table 4.1 gives the sub process performance baseline for TCEDD. The values are represented by D1, D2, and D3 and so on. Organization Metrics team would have the actual baseline values for LSL, Goal and USL for these identified metrics. Based on the current project context, the parameters and rounds of testing chosen are shown in Table 4.2, Selected Sub process performance baseline.

Table 4.1 - Sub process performance baseline

Sub process	Metric	Parameter	LSL	Goal	USL
Test case execution review	TCEDD	1 round of testing	D1	D2	D3
Test case execution review	TCEDD	2 rounds of testing	E1	E2	E3
Test case execution review	TCEDD	3 rounds of testing	F1	F2	F3

Table 4.2 – Selected Sub process performance baseline

Sub process	Metric	Parameter	Goal	Comments
Test case execution review	TCEDD	3 rounds of testing	F2	

6. TEST EFFECTIVENESS MODEL – PRACTICAL USAGE

One of the current releases in design phase was considered for the practical usage of this model. The below steps will illustrate the prediction model.

1. X factors baseline data was used as input. Domain experience goal is 32 months with LSL of 15 months and USL of 51 months

2. Sub process performance baseline data was reviewed and based on the current project context the below selection was made. As shown in Table 5.1 the sub process test case execution review was selected. Based on the project usage, 3 rounds of testing were selected for test execution. The goal, upper specification limit and lower specification limit are chosen from organization baseline report.

Table 5.1 – Selected Sub process

Sub process	Metric	Technology	LSL	Goal	USL
Test case execution review	TCEDD	3 rounds of testing	0.32	**0.69**	1.24

3. Update the actual domain experience in the team and predict the test effectiveness. The predicted value is based on Monte Carlo simulation.

TableTable 5.2 – Predicted Test effectiveness

Average Domain Experience (in months)	TCEDD (Defects/ Personday)	Predicted Test effectiveness
32	0.50	90%

4. The data was compared against goal. The client goal for test effectiveness is 99% whereas the predicted value is 90%.
5. Perform what-if analysis and look at various combinations of the x factors and analyze the predicted test effectiveness based on these factors. Based on the project experience choose the one which is close to reality.
6. List down the assumptions considered when the final decision is made on the values of x factors. Ensure all the relevant assumptions are documented. As need be, the assumptions need to be validated with the relevant stakeholders before the baseline process.
7. Understand the deviation and prepare preventive action plan

Table 5.3 – Deviation Analysis

Expected client test effectiveness	Predicted test effectiveness	Preventive Action	Responsibility
99%	90%	List down the top three preventive action items	Project Manager

8. Estimated effort in person days for the project is 500 person days. Based on the predicted defect density and organizations standard effort distribution across phases, the defects that could be injected at each phase are predicted as show in Table 5.4

Table 5.4 – Predicted-Actual Defects phase wise

Phases	**Expected Injection**	**Actual Defects Captured**	**Remarks**
System test cases execution			
System integration test Execution			

9. Based on the actual data collated, keep updating Table 5.4 to compare the expected and actual defects captured. Based on the actual value in each phases, the predicted value for next phases are accordingly impacted. If there any specific inputs or considerations on the actual values, those are highlighted in the remarks column.
10. Prepare the detailed defect prevention plan. Against each phase, list down the defect type, defect cause, root cause, preventive action planned, responsible person, target date and the status. Defect types could be incorrect functionality or missing functionality or incorrect user interface or missing user interface. Defect causes could be lack of knowledge, missing information or incidental. Root cause should be as detailed as possible to plan for preventive and corrective action. 5-Why analysis can be used to identify the root causes. Defect prevention plan is an on- going document that need to be tracked very closely. It is meant both for planning and tracking defect prevention activities. This plan has to be revisited after completion of each stage. If defects detected during the completed stage fall under different defect types and defect causes not identified for preventing at that stage, then these new types need to be included in the on-going phases.

8. CONCLUSION

Most of the customers demand 100% test effectiveness. It is a service level agreement in the statement of work as initiated by the clients. A metric that needs to be tracked on monthly basis and deviations with corrective actions are to be reported. Certain customers even demand penalty clauses based on the criticality of the project. Given the importance of testing, the ability to predict test effectiveness using process performance models plays a major role. Test effectiveness is directly related to the product defects in turn to customer satisfaction. Capability Maturity Model V1.2 recommends use of quantitative models to predict project outcomes. The practical implementation of test effectiveness process performance model in life science project was demonstrated. This is an on- going process which managers should use day in and out. Predicting project metrics and quantitatively managing by pro-actively taking preventive actions is the success factor. This illustration gave the practical applicability of test effectiveness model in life science testing projects thus helping to reduce residual defects.

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