Al Ain Risk Based Test Approach for Independent Verification and Validation Test Case Design

Shahjerome Ambrose, Massila Kamalrudin

Abstract--- Independent Verification and Validation (IV&V) involves testing activity that is done by a third party independent from development activities of a product. A key activity for this third party is to conduct agreed examination to determine requirements are met and to also ensure a product is developed with quality and expectations are consistent with the customers' expectation.

This paper discusses a proposal for an improved software Independent Verification & Validation Model-based test design using Risk Based Test approach. This approach depends on a set of selected criteria that can help to provide risk assignment using Traceability Matrix as a reference point and a dynamic tracking approach using outcome of the development and V&V results that will help to prioritize test case allocation, to improve effectiveness and to discover defects for the IV&V team. This approach is also examined from a tester's perspective by helping IV&V engineers to discover efficient method of identifying and documenting various stages of product development and test.

Keywords: IV&V, Requirements; Risk Based Test; Traceability Matrix, validation; correctness; completeness.

I. INTRODUCTION

IV&V can be described as following:

Independence - Assessment conducted by a third party. *Verification* - verification of engineering of the product

Validation - product is consistent with client expectations [1]. Independence - is referred to IEEE Std 1012 - 2004 [1] that describes three major areas of independence as below: *Technical Independence* - IV&V team independent of the development team. *Managerial Independence* - responsibility of the team building and deployment of product separated from IV&V team. IV&V activity is tailored according to the project need or in some cases such as government binding by guidelines or handbooks. *Financial Independence* - funding for IV&V effort is independent of project fund. This is motivated by the need to protect the IV&V team from any financial pressures. The focus of this write up will focus on Validation phase of IV&V team activity, where IV&V team's efforts are largely focused on measuring or assessing the product tested by development team.

Our proposed method also determines the risk from available data based on Validation attempts as well as to established documented evidence, which may be a product or a service, or a system. The final aim of proposed testing method is to test the product that accomplishes its intended requirements consistently with the user expectation.

II. Literature Review

2.1 Several researchers had explored various types of testing methods, which are lack of cohesive communication of outcome, where risk associated with test status. According to SDLC V-model, where Verification is the phase from Requirements, Design and Coding. Validation is made of phases that include System Integration Test(SIT), System Test(ST) and User Acceptance Test (UAT). Example of a V-Model engagement for IV&V is provided is recent handbook provided by Malaysian Administrative Modernization and Management Planning Unit (MAMPU) in it overview of IV&V service. Figure 1. below.

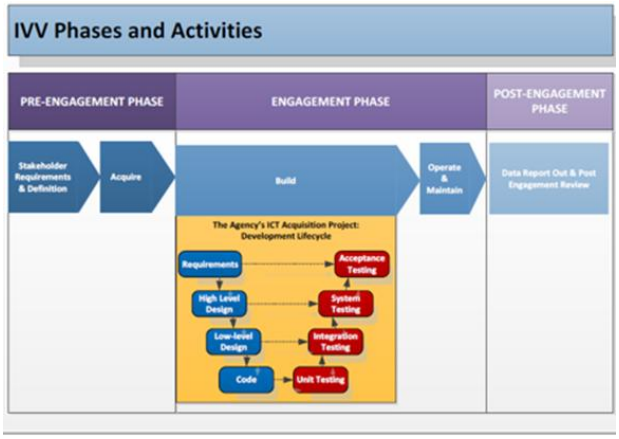

Figure 1: V-Model to describe various stages of development and IV&V involvement. [2]

2.1.1 Risk Based Testing

A software Risk can be tagged as a potential problem that could impact outcome of a Project. The mathematical notation of software risk is described in Equation 1 [3]

$$Risk = \sum p(E_i) * c(E_i) \text{ Eq (1)}$$

Where,i =1,2,…,n. n is the number of unique failure events, E_i are the possible failure events, p is probability and c is cost.

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The aim of Risk Based testing is to identify and prioritize as many scenarios as possible based on risk, determine a suitable test that can detact or identify the risk and help stakeholders make the required actions to address the risk.

2.1.2 IV&V Risk Based Testing Activity

The IV&V testing team performs the product evaluation via risk based testing and analyses its test results performed by project test team. This analysis provides an independent assessment of the product with respect to readiness prior to deployment at staging and production environments. [4]

It is impossible to test a software system exhaustively, a good sampling activity is important in our proposal.

Risk based testing has been covered in various risk management approaches, which are used to influence test case design. As per test case design especially risk assessment model using probability and impact by Felderer at el [5] that suggest calculation of probability and impact metrics based on system artefacts which formalized as model elements.

Risk analysis and also how it can be used to provide alternative consideration to projects are well captured [6] in NASA RIDM handbook. This is a good reference to indicate how information from RISK based decision making and risk informed alternative selection concept is explained. Risk based test design especially for E-Business was covered by P Gerrard[7] where the focus was to provide an overview of risks of E-Business and a framework to create E-Business test strategy. The defect tracking and management is to determine test strategy [8]. This approach aligns with various types of defects and behaviours of defects if various phases of software development. This also relates very closely with [9] a list of extensive defect taxonomy.

III. Proposed Testing Methodologies

We take a pragmatic view of challenges faced by testers and how testing is not just about executing test cases but also the important need for testers to identify failure modes and translate these into consequences to the stakeholders of the project. Defects are a very important part of our design because in our model we recommend that testers modify risk according to types of defects found and development phase it is found [10]

3.1. Current proposed Approach to Testing

The common approach to testing involves a reference to requirements which is followed up with the design and test case scripts, which aim to prove the requirements and products under test are consistent where requirements goals have been met. This approach has its limitations as described by Paul Gerrard[11]. Where traditional testing is leads to decision making that is: -

a. Timescale driven in early stages
b. Crisis Driven towards the end
c. Unsatisfactory all round.

This is a type of end to testing that leads to arguments between product management (most stakeholders) and test managers on the merit of release.

Figure 1 shows the final stage of release that can cause confusion if there is no clear focus on impact of outcome to make a decision to release.

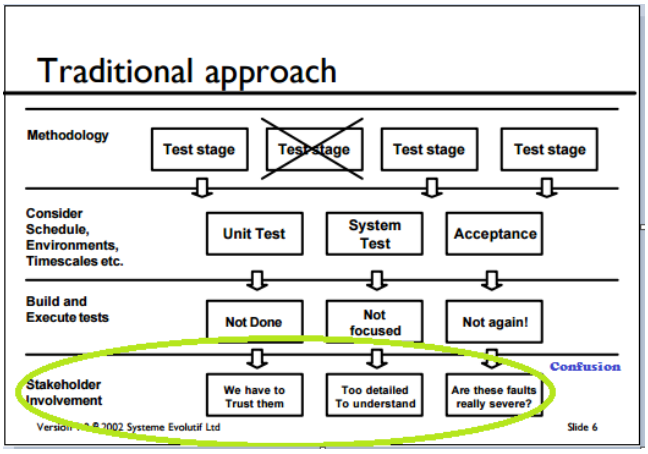


Figure 1: Traditional Approach[11].

3.2 AlAin-Approach

Based on motivations mentioned above we have developed an approach that can help testers to use risk-based test case design called AlAin RBT. AlAin IV&V model employed the use of Risk-based test case design approach. The aim of this approach is to provide IV&V test team sufficient guide to prioritise and effectively recognize test cases or scenarios that should be tested over other using our risk-based test approaches and communicate a snapshot of project status using heat map. Here risk rating is used to determine the amount of risk and it is based on the non-exhaustive list as follows:

a. Include static review findings i.e Requirement Documents Review
b. Features developed and its priority to users
c. Test conducted by development i.e Unit Test Coverage
d. Defect distribution by modules, stage of discovery
e. Criticality of defects or other criteria agreed

Risk based testing helps prioritize test cases based on the above and this list is non-exhaustive where other conditions can be added if required.

Our approach uses traceability matrix to map requirements to test case. Risk is determined by Probability and Impact that is rated based on the following:

a. Completeness of coverage of test covered by development that is tracked with traceability matrix
b. Defects found in development and test phase
c. Using traceability matrix, the sampling of test cases to test scenarios are mapped to ensure completeness

Based on ratings provided in a, b and c, the criteria used, allows to identify relevant test cases to be tested based on risk to business.

The proposed approach helps a IV&V team to identify areas most likely to fail with relevance to business. The proposed approach increases the probability of finding the defect rate, in a shorter time with less documentation and flexible test execution, and helps prioritize risk to business impact.

Risks are mapped to a heat map. The heat map is based on guideline provided by Chartered Global Management Accountant (CGMA) [12]. Although there is a difference in

discipline, the risk assessment heat map model based on Risk Matrix used does help to explain the simple ratings used in our approach.

i. Assess Risk Process Flow

A challenge that is faced by teams assessing risk is to determine where to start, where to finish and when? In order answer this question it's important to agree on an Assessment Process Flow. The IV&V team can use this flow to start a selection criteria as early as possible in the development process.

Risk assessment here is done with the aim of 'measuring', tagging and prioritizing risks so that risk identified using our approach can help IV&V teams to better plan and execute test cases and justify the approach based on Risk. With informed risk that is properly measured and clearly communicated to various stakeholders in a project such as Project Decision Makers, Subject Matter Experts and Technical Analysts there can be better deliberations to support informed decision making [6]. The alternatives that is available provides the project stakeholders to select alternatives based on available options. This will lead to better attitude for tolerance level and provide opportunity to increase or opportunity to adjust or change direction if required.

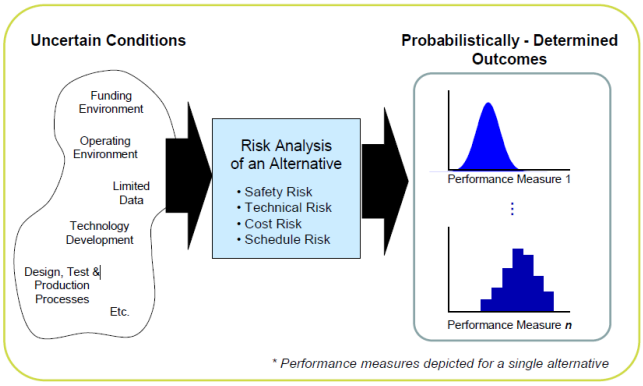


Figure 2. Uncertainty of Forecasted Outcomes Due to Uncertainty of Analyzed conditions. [6]
Figure 1: Risk Assessment Process Flow

Identification

Identification – It identifies the functional components that fail in a system. It's important to consider that no matter how testing is done there is always a danger of failure. The more relevant question would be how much minimum amount of test investment to maximize risk reduction [13]. Then Non-Functional components that can fail (example performance, availability) [14] and Regulatory conditions (Standards) [15] as well as 3rd Party dependency.

1. Analysis - Criteria Used (probability of failure and impact). In this analysis the IV&V team can tag a rating to the non-Compliance in Requirement gathering, gaps in design or defects in development test to indicate a potential to contribution to risk. Example below

I. Defects found in development and test
- V&V – compliment coverage by V&V team to optimal scenarios
- Defect Find Rate – number of defects found in unit test and V&V

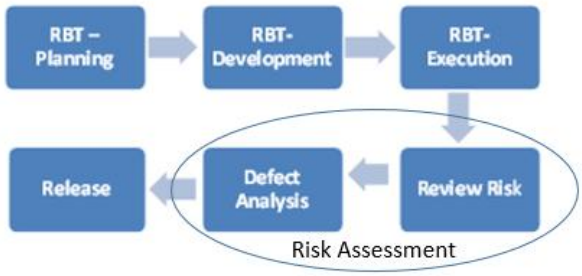
II. Gaps in Requirements
- Traceability Matrix (TMX) Coverage – can include mismatch between Details Requirement ➔ High Level Requirement ➔ Statement of Work (SoW)
- This gaps identification is important for early test on how intent and statements captured in early Statement of Work transpires into requirements that will then be used for Design Phase.

All example above contributes to a rating that is described further in 1.7 Overview of AlAin Approach.

Risk Exposure is assumed by using a simple rule that accumulates probability of failure and Impact Risk to user (Business)

ii. Designing Test Case

Based on RE (Risk Exposure) that is identified during evaluation of project deliverables. The IV&V team can use this information to design a test approach to create test cases and identify Uses Cases that would help to testers design test cases based on suitable test techniques. We believe that test technique most suitable for testing can be determined by the test scenario. For example, a usability test is better suited to test, how a user will use a system as compared to a test scenario to measure performance (i.e. page load time).



3.3 Establish the IV&V Plan

IV&V Team must objectively evaluate a project to ensure customer perspectives on quality are addressed. Below is a list of IV&V functions that IV&V team can use to establish an IV&V test plan.

1. Evaluate project process and provide evaluation report at major milestones
2. Verify project deliverables for conformance to agreed templates and specifications.
3. Review business and system requirements
4. Review system architecture and design
5. Analyse testing results from the various test phases
6. Recommend Risk identified/evaluation for each phase

i. Perform risk-based test as a form of validation

Provide recommendation on the readiness for System deployment as defined and agreed with relevant stakeholders

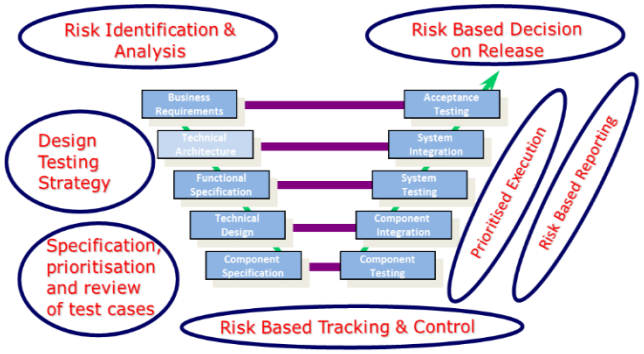


Figure 4. Note:Diagram above provides a simple list of assessment and development phases.

Our Finding

In our research we applied the AlAIn approach for IV&V team to use a template that included.

a. Test Matrix
b. Test Case Design Template which included columns that contain values for
   i. Risk Rating
   ii. Test Case Priority
   iii. Test Estimation
c. TestStatus Tracking Reporting Template

1.1.1 Observation 1

Where test cases were mapped to risk by use of scenario test technique [13] and a critical path is derived based on scenario or actor. This provided a base to create critical path of test scenario and priority. In some cases, a logical decision tree to was applied where the test technique was adapted to match the scenario. The final outcome provided the testers with a guideline where business functionality was rated Hi, Med, Lo on the basis of relevance to business.

1.1.2 Observation 2

The team also was able to modify test strategy based on quality of AUT (Application Under Test). In most test projects test case design and scripting is started in parallel with coding and the test team is left with a very 'heavy' of modifying test cases where there are changes to product design or scope change.

Because our approach only maps the scenarios with little step by step requirement to write test cases the testers were able to adjust much quicker with little overhead compared to a team using traditional approach of writing out all test cases and in fact just mapping out the requirements as test cases.

1.1.3 Observation 3

Our approach was able to provide risk rating based on project overall need and potential impact versus a project progress metrics that is usually provided by a run rate chart, burn down chart or defect find rate chart.

A team of 5 IV&V testers were tasked to use this approach in 5 rounds of testing.

The following are our findings.

1.1.1 **Finding 1 Early Test** is usually associated with Shift Left and we started our evaluation as early as possible by reviewing completeness of documents. Our approach with the use of Traceability Matrix and mapping out completed, requirements still partially completed or missed was captured and tracked in a readiness heat map that allowed the team to track test cases and save time on rework.

1.1.2 **Finding 2 Focus efforts** in areas of product that can have high risk of failure. Defects distribution found by IV&V was consistent with the defect ratio found by the V&V team.

1.1.3 **Finding 3 Reduce time** to write test cases

Because the IV&V team did not write test scripts and used a simple approach of mind map that mapped to requirements the team did not have to spend too much time to re-write test cases. In fact, IV&V team only had to move the test scenarios to match changes on the requirements.

Which made this exercise a very light weight approach for use by IV&V team.

1. Change test strategy according to areas of risk
   a. The team was also able to change test strategy based on area of test completed by the development and V&V team to focus only on area required for testing.
   b. The team was able to save time by not having to execute test cases for features that were not ready for testing by V&V
   c. The IV&V team also was able to decide on areas that was ready for testing and able to highlight to stakeholders on product readiness for release.
2. Heat map A – Test Readiness

Readiness Heat map is a test case readiness tracking that the teams were able to create with the use of AlAin-RBT approach.

Conclusion:

The team was able to clearly see readiness of deliverable for testing. With this the IV&V team was able to determine Modules that are ready for evaluation and provide an assessment before having to execute any test cases.

Legend 1 – refers to Table 1 Heat Map A

Legend (Risk ased Test)

	Complete critical path, can be tested
	Can test multiple UC together
	Can test individual UC

Legend 2 – refers to Table 1 Heat Map A

No	JIRA-Release	Module	Use Case	Tester	Test Result Status			Comment	Test Result	Estimation
					Positive	Alternate	Negative			
1	[TPC-26460] - Get Registration Item	Bills	BM-I-20	Wei						
2	[TPC-3076] - Remove Client From Community	Out Reach	SO-2-2	Shah	Pass	Fail				

Table 1 Heat Map A

IV. Heat map B - Test Case Status

The IV&V team was also able to change the test strategy to evaluate areas in the product that was ready from development to be tested in parallel with V&V. This was a change is direction from earlier plan due to change in project timeline.

Legend (Test Cases by individual Use Case only)		UC	Test Status %
Pass	Use case specific & NOT for IV&V critical path test cases	56	5.37%
Fail	Use case specific & NOT for IV&V critical path test cases	172	16.51%
Block	Use case specific & NOT for IV&V critical path test cases	132	12.67%
	Use case which not Tested	682	65.45%
Total		1042	100.00%

Module									
Admin	Use Case	AM-2-1	AM-2-2	AM-2-3	AM-2-4	AM-2-5	AM-2-6	AM-2-7	AM-2-8
	Test Result	Block	Block	Block	Block	Block	Block	Block	Block
	Use Case	AM-3-3	AM-3-4	AM-3-5	AM-3-6	AM-3-7	AM-3-8	AM-3-9	AM-3-10
	Test Result				Fail	Block	Fail	Block	Block
	Use Case	AM-3-23	AM-3-24	AM-3-25	AM-3-26	AM-3-27	AM-3-28	AM-3-29	AM-3-30
	Test Result	Fail	Pass	Pass	Fail	Block	Block	Block	Fail
	Use Case	AM-3-43	AM-3-44	AM-3-45	AM-3-46	AM-3-47	AM-3-48	AM-3-49	AM-3-50
	Test Result	Fail	Pass	Pass	Pass	Fail	Pass	Pass	Pass
	Use Case	AM-3-63	AM-4-1	AM-4-2	AM-4-3	AM-4-4	AM-4-5	AM-4-6	AM-4-7
	Test Result	Fail		Fail				Block	Block
	Use Case	AM-6-3	AM-6-4	AM-6-5	AM-6-6	AM-6-7	AM-6-8	AM-6-9	AM-6-10
	Test Result	Block				Fail	Fail	Fail	Block
Billing	Use Case	BM-1-3	BM-1-4	BM-1-5	BM-1-6	BM-1-7	BM-1-8	BM-1-9	BM-1-10
	Test Result								
	Use Case	BM-2-3	BM-2-4	BM-2-5	BM-2-6	BM-2-7			
	Test Result								
	Use Case	BM-3-3	BM-3-4	BM-3-5	BM-3-6	BM-3-7	BM-3-8	BM-3-9	BM-3-10
	Test Result				Block				
	Use Case	BM-5-2	BM-5-3	BM-5-4					
	Test Result								
	Use Case	CD-1-3	CD-1-4	CD-1-5	CD-2-1	CD-2-2	CD-2-6	CD-3-1	CD-3-2
	Test Result				Pass	Fail		Fail	Fail
	Use Case	CD-6-1	CD-6-2	CD-6-3	CD-6-4	CD-6-5	CD-9-1	CD-9-2	CD-9-3
	Test Result	Fail	Pass	Pass	Fail		Fail	Pass	Fail
	Use Case	CD-5-3	CD-11-1	CD-11-2	CD-11-3	CD-11-4	CD-11-5	CD-11-6	CD-12-1
	Test Result		Fail	Fail	Pass	Fail	Fail		
	Use Case	CD-14-3	CD-14-4	CD-16-5	CD-16-1	CD-16-2	CD-16-3	CD-16-4	CD-16-5
	Test Result			Fail					Block
	Use Case	CD-33-3	CD-33-4	CD-33-5	CD-34-1	CD-34-2	CD-34-3	CD-34-4	CD-34-5
	Test Result			Fail					Fail
	Use Case	CD-18-3	CD-18-4	CD-19-5	CD-19-1	CD-19-2	CD-19-3	CD-19-4	CD-19-5
	Test Result			Fail					Fail
	Use Case	CD-22-3	CD-22-4	CD-22-5	CD-17-11	CD-17-12	CD-17-13	CD-17-14	CD-17-15
	Test Result			Fail					Fail

Table 2 Heat Map B

iii Risk Tracking

Our approach to measure is to track two key KPI

a. Test Readiness

b. Defect find rate

What is test readiness? Test readiness is a measure that is typically used in test to qualify entry criteria for test team to start test phase in this case it could be a measure of percentage of test cases passed to an arbitrary number of test cases that is communicated to project.

An example would be to use a 100% feature complete to indicate readiness for testing to start. In the event the product is not 100% ready at the time of entry into phase the test team would have the option to say that testing could not start as the cost of starting test could actually by expensive where test cases may need to be repeated in case of high number of defects or incomplete product.

For our example the product was tested in a cycle that can be best described as in active development phase where there are incomplete features and defect find rate is expectedly high.

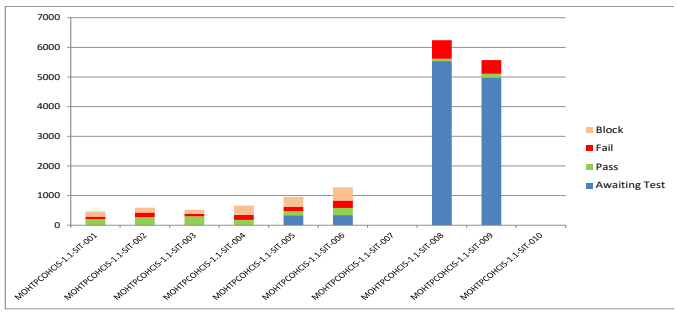


Figure 3.5 V&V Test status cumulative chart

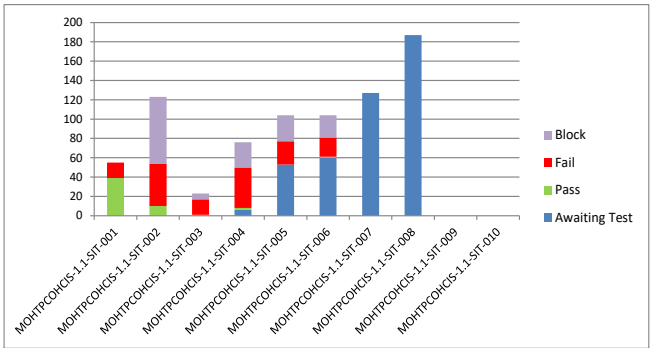


Figure 3.6 IV&V Test Status

How was controlled achieved?

Control was achieved by using same builds on different environmental

The number of defects found in Env 1(V&V) vsEnv 3 (IV&V) is recorded below.

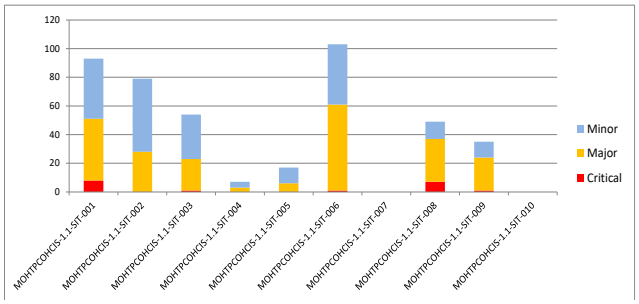


Figure 3.7 The defects found by V&V IV&V Defect

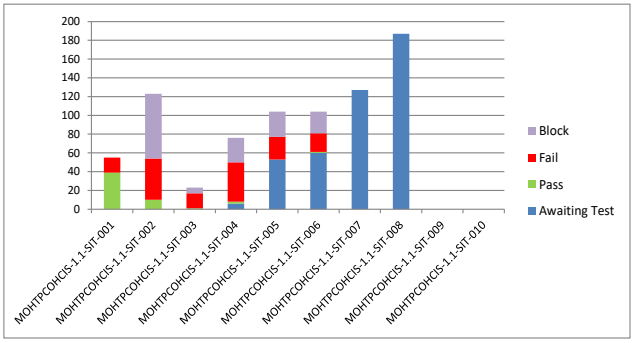


Figure 3.8 Defects Found by IV&V

We are able to conclude the following on the controlled setup both V&V and IV&V achieved a defect ratio of around 3:1 which means there were 3 defects for every ten test cases that was run. This is a very important statement to support the effectiveness of RBT to capture defects.

Referring to Figure 3.7 and 3.8 the key finding is over the period of 6 builds the defect find rate of cumulative chart from V&V team is Fail 300; Pass 300, Blocked 400 and awaiting test 400 test cases. For the 1200 test cases attempted (Fail + Pass + Blocked) there is a ratio of 3 to 1 where for every 1200 test cases attempted the number of failed or blocked test case is for every 2 attempted there was 1 test case that failed or was blocked.

IV&V test outcome was not too far away because the IV&V team was able to also achieve a ratio of 360 : 304 make the average of 1.18 ratio of failed or blocked for test cases attempted.

3.3 Observation

We also conducted observation of test scenarios that was run by both V&V and IV&V test teams. The size of IV&V was only 3 testers compared to 10 testers in V&V

From the following criteria that coincide with the problems that we have raised.

a. Re-plan with increased changes to requirements

We have tagged this Y for both teams but the challenge for V&V team is the expectation of completing coverage while the expectation of IV&V team is to provide risk.

IV&V team need to use RBT as a means to identify readiness to execute test case as well as to capture defects

b. Overhead of reporting/documentation

V&V used a step by step test case writing approach vs an exploratory approach adopted by IV&V. Because the objective for V&V is to communicate coverage to highlight risk IV&V did not need to use the same approach and used RBT to identify readiness for test as well as test case writing was simplified to track use case flow or business scenario flow

IV&V also did not have to readjust as frequently or re-write all the steps created when frequent changes occurred later on in the project.

3.4 Controlled Independent Variable Observation

In this section, we discuss the controlled independent variables in our controlled observation. There are two controlled independent variables, namely the test design approach and test environment used.

3.4.1 Test Design

The test teams from V&V and IV&V had very different test design approach where the V&V used a standards optimal path coverage approach while IV&V used a RBT approach. Both teams referred to same versions of Requirements and worked in the same project.

V. Summary

Our approach can be focused on 5 main areas refer to Figure 4

a. Scope
b. Implementation
c. Testing
d. Risk Assessment
e. Release

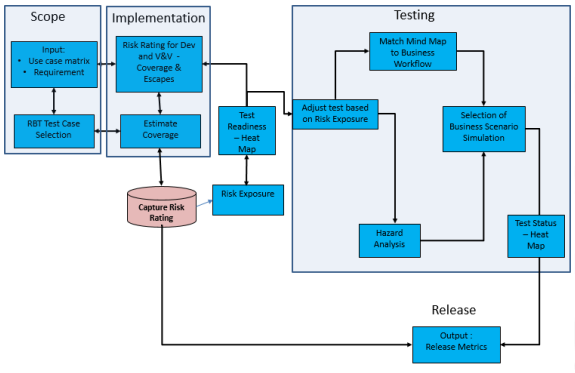


Figure 4. Overview of approach.

iv. Scope

Focused on Requirements for the project and this is focused on Use cases, Documentation completeness, Accuracy of documents that would allow for early test. This was important as the project progressed to ensure the customers expectations that was captured in requirements match Implementation.

v. Implementation

Implementation referred to the coding, testing by development as well as reviews with stakeholders to ensure the product mapped to user expectations.

Both Scope and Implementation were important input to Estimated Coverage. Defects, and any inconsistency in implementation would feed into estimated coverage. All of which contribute to Estimated Coverage. In our observation there was also increase in RISK especially when the inconsistency of Changes made to requirements due to wrongly captured requirements had impact to overall estimate. We did not factor in Change Request since it is deemed to be an addition to scope that would need revisit to budget and scope.

viii. Testing

Testing refer to 3.2 AlAin-Approach above.

ix. Risk Assessment

Risk Assessment was tracked using

a. A base reference i.e Traceability Matrix
b. Post V&V
c. Pre V&V

What happens from start to end of a project is factored into measurement or weightage of risk factor. This aims to capture the reality of projects Agile, V-Model or Waterfall the fact that the same times may not participate in development and delivery of a product. The gaps that could occur between and requirement and actual product is tracked and identified as much as possible.

The advantage of our approach is it does not just measure the product from a perspective of delivered product but also how the end product is also required to meet requirements of contract, regulatory requirement and meet customers objective.

x. Release

We were able to map Heat Map and Project release criteria to communicate release readiness to stakeholders.

We observed the of Heat Map B allowed stakeholders to individually decide relevance of features ready for next phase of development and not necessarily release. Example would be during System Test, stakeholders we willing to allow selected features to be developed in parallel during UAT phase that was expected not to have a adverse effect on quality.

Conclusion

We aim to develop an automated tool to improve test design for IV&V teams with the use of traceability matrix to link dependency of use cases/requirements to map risk and improve the approach with use of development and V&V quality considerations to be factor as contributing to risk factor.

This tool will help IV&V tester to build an early coverage map of risk associated with product feature based on complexity of requirements and also outcome of development and V&V. The impact on IV&V project will be to improve cost savings and time to test.

Reference

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