Available online at www.scientiaresearchlibrary.com

Scientia Research Library

**Journal of Engineering And Technology Research,
2013, 1 (1):42-56**

(*http://www.scientiaresearchlibrary.com/arhcive.php*)

Test Maturity Model Integrated Technique for Enhancement of Software Testing Process in Organizations

Maurya Vishwa Nath[1], Maurya Avadhesh Kumar[2], Singh Dibyanshu[3], Priyadarshi Anurag[3], Anand Gaurav[3], Ateeq Nida[3]

**Department of Mathematics, School of Science & Technology, The University of Fiji, Saweni, Fiji*
Department of Electronics & Communication Engineering, Lucknow Institute of Technology, GBTU, India
Department of Computer Science & Engineering, Sapthagiri College of Engineering, Bangalore (Visvesvaraya Technological University, Belgaum, India)

ABSTARCT

Present paper deals with problems of inhancement of software testing process. In this paper, a test maturity model integration (TMMI) criterion has been used to improve testing process in software organizations. Many organizations find value in benchmarking their progress in test process improvement for not only internal purposes but also for external customers and suppliers. Here it is relevant to mention that the TMMI provides an excellent reference model to be used during such assessments. Assessment teams use TMMI to guide their identification and prioritization of findings. These findings along with the guidance of TMMI practices are used to plan improvements for the organization. This application helps in evaluating projects under various companies using TMMI levels and standards and hence, generating reports in form of graphs showing the areas that need to have improvement. This paper contains 9 sections and outline of several sections has been organized as follows. Section 1 enables a brief introduction and section 2 summarizes literature survey. In 3rd section, we focus on test process improvement wherein ***Error! Reference source not found.****. In the 4th sectin test maturity model integrated (TMMI) has been demonstrated. Minimal test practice framework (MTPF) has been discussed in the 5th section. Choice of framework and TPI assessment have been appropriately discussed for test improvement model (TIM) in section 6 followed by tables 6.1-6.7 describing the checkpoints and the results from the assessment where each table represents a key area. Section 7 provides TPI Assessment summary and section 8 provides significant results. Finally, possible improvement suggestions have been explored in section 9.*

Keywords*:* TMMi; test process improvement (TPI); test improvement model (TIM); maturity matrix; quality assurance; minimal test practice framework (MTPF)

INTRODUCTION

Many software companies find value in benchmarking their progress in test process improvement for not only internal purposes but also for external customers and suppliers. Here it is noticeable that the TMMI provides an excellent reference model to be used during such assessments. Assessment teams use TMMI to guide their identification and prioritization of findings. These findings along with the guidance of TMMI practices are used to plan improvements for the organization. This application helps in evaluating projects under various companies using TMMI levels and standards and hence, generating reports in form of graphs showing the areas that need to have improvement. The Company's objective is to get to a situation where all products are following the same system test process. Here, our objective is to identify appropriate and viable improvements of the current system test processes and to explore the maturity of the software testing process for three products from the Company. A first step towards a more mature test process includes a literature survey of different test process improvement frameworks. One of those frameworks will be used as a reference model and it will be helpful when identifying improvements for the test process. To be able to know what level of maturity the Company is at today an assessment was executed for the three products.

MATERIALS AND METHODS

In this section test process improvement frameworks are presented. Several noteworthy reasearchers [1, 2, 3.....20] confined their attention to contribute for improvement of software testing process in different frameworks. The reason for choosing two of them test process improvement (TPI) and test maturity model integrated (TMMI) is that these two frameworks are widely known; for more details see Kollman and Pol (1999) and Veenendaal (2009). The other two testing techniques-minimal test practice framework (MTPF) and test improvement model (TIM) are also chosen because they aim at small and medium sized companies and would be interesting to compare these two with the more known TPI and TMMI. Here, in this connection, research works carried out by some noteworthy previous researchers Ericson et al [1] and Karlstrom et al [4] are worth mentioning. Moreover, it is noticeable fact that these frameworks share the same fundamentals up to some extent. TMMI, MPTF and TMI are staged frameworks which means that the companies need to address all process areas in one level and a level cannot be skipped. It helps to focus on a limited set of process areas before moving on to the next level. TPI is a continuously based framework and this means that the companies can be more flexible to choose process areas that the companies find more important to implement.

However, test maturity model integrated (TMMI) technique requires more commitment from the organization from the start than TPI that may be implemented on individual projects without strong commitment from the organization because it gives more freedom in what key areas to focus on; we refer Veenendaal (2009).

1. Test Process Improvement

Test process improvement (TPI) is a framework developed by Tim Koomen and Martin Pol at Sogeti Netherlands; for more details we refer Fewster and Graham (1999). The framework is also published as a book and was released in 1999. The framework is based on knowledge and experience in testing collected at several companies. The model is divided into 20 key areas which cover the whole test organization. Each of the key areas is divided into levels of maturity ranging from A to D, but some of the key areas do not go as far as D. Each of the levels has a number of checkpoints for each key area and these checkpoints are the requirements for the level so to reach a certain level, the test organization needs to fulfill these checkpoints. For each level there is a section that describes some improvement suggestions, these can help the organization to satisfy the checkpoints for the next level.

The level of maturity differs for each key area and level A for two key areas might not share the same level of maturity. The maturity matrix which is provided by TPI ranges the maturity of the key areas into a matrix where columns represent the maturity level 0-14 where 14 is the most mature level and the key areas represented as rows. **Error! Reference source not found.** shows the maturity matrix.

Table 1.1 TPI Maturity Matrix

Key area	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Test strategy		A					B				C		D	
Life cycle model		A			B									
Moment of involvement			A				B				C		D	
Estimating and planning				A							B			
Test specification techniques		A		B										
Static test techniques					A		B							
Metrics						A			B			C		D
Test automation				A				B			C			
Test environment				A				B						C
Office environment				A										
Commitment and motivation		A				B						C		
Test functions and training				A			B			C				
Scope of methodology					A						B			C
Communication			A		B							C		
Reporting		A			B		C					D		
Defect management		A				B		C						
Testware management			A			B				C				D
Test process management		A		B								C		
Evaluation							A			B				
Low-level testing					A		B		C					

2. Test Maturity Model Integrated (TMMI)

TMMI have been developed by the TMMI foundation as a complement to CMMI that is a process improvement approach for organizations developing software, we refer Veenendaal (2009) but TMMI address the test process more detailed. TMMI is a staged model that uses the concept of maturity levels. The TMMI model consists of five different stages where the initial level 1 stage is where every company belongs to until they fulfill every process areas in level 2. The process areas indicate where the organization should focus to improve its test process. Each process area consist of several test related activities that needs to be fulfilled to reach the next level. TMMI is often called top-down model because many of its initial process areas requires strong commitment from the management compared to TPI that is called bottom-up. TPI can be more suitable to address test improvement for a specific project without needing strong commitment from management.

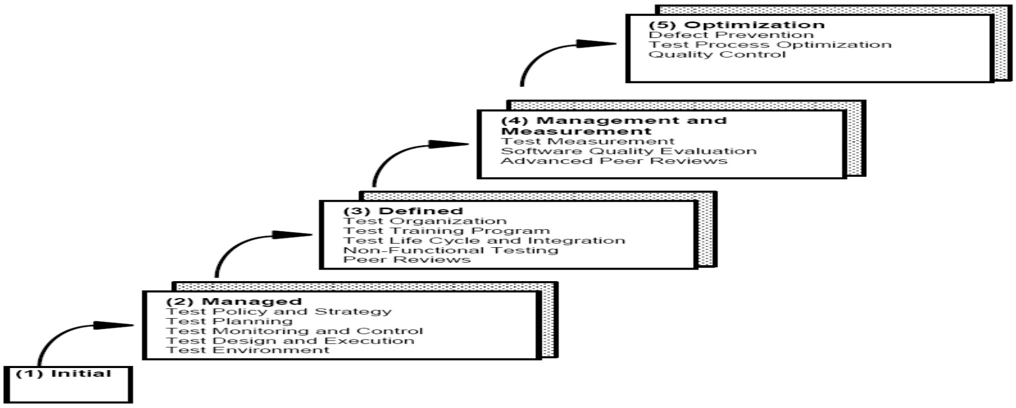

Figure 4.1 TMMI maturity levels and process areas

3. Minimal Test Practice Framework (MTPF)

MTPF is developed with the small and medium sized company in mind where more complex process models like TPI; we refer Karlstrom et al [4] and TMMI are too extensive. MTPF is structured in five categories and is leveled in three phases. The first phase includes practices that are suitable for a company with approximately 10 developers. The second phase is including practices suitable for approximately 20 developers and so on. The idea is that as the organization grows the new practices solve the new issues created in the new larger organization. After the third phase a fourth phase could be appropriate but then the organization should start looking at TPI or TMMI instead.

4. Test Improvement Model (TIM)

TIM consists of five different levels and each level has a different setup of key areas; we refer for more details Ericson et al [1]. The first level is a non-compliance level where every company starts at. To complete a level all key areas must be fulfilled. Normally to move on to the next level the all key areas must be fulfilled within the level but some organizations could start working on key areas from another level but a balanced improvement approach is recommended.

4.1 Choice of Framework

Both MPTF and TIM are aimed at small companies and could be used at The Company but limited information could be found on where those frameworks have been successfully implemented. More information could be found on TMMI and TPI as they are more widely used and gathered experience from many different companies.

Our choice of framework is TPI as is requires less involvement from the organization and gives more freedom when choosing process areas to focus on that The Company find useful.

4.2 TPI Assessment

Due to limited time our TPI assessment is restricted to the first seven level one key areas (Test Strategy, life-Cycle model, Test Specification Techniques, Commitment and Motivation, Reporting, Defect Management, Test Process Management).

To be able to complete the assessment interviews with responsible tester was held for each product. Also a survey of available test documents which consisted of test plan, type test records, type test description and test surveys was done. After the assessment we reconciled our assessment with the responsible testers.

The following tables 6.1-6.7 are describing the checkpoints and the results from the assessment where each table represents a key area. The first part of each table consist of the level A checkpoints for the key area provided by TPI, see for more details Koolman and Pol (1999). Below the first part of the table a motivation and result for each of the products are presented.

Table 6.1: Key Area 1: Test Strategy

Nr.	**Key Area** / *Level* / Checkpoint	
1	**Test strategy**	
1.A	*Test strategy for single high-level test*	
1.A.1	A motivated consideration of the product risks takes place, for which knowledge of the system, its use and its operational management is essential.	
1.A.2	There is a differentiation in the depth of the tests, depending on the risks and, if present, depending on the acceptance criteria: not all subsystems are tested equally thoroughly and not all quality characteristics are tested (equally thoroughly).	
1.A.3	One or more test specification techniques are used, suited to the required depth of the test.	
1.A.4	For re-tests also a (simple) strategy determination takes place, in which a motivated choice between 'test solutions only' and 'full re-test' is made.	
1	**Test strategy Product A**	**OK**
1.A	*Test strategy for single high-level test*	
1.A.1	A risk analysis is made. (Based on interview)	OK
1.A.2	The parts of the system with high risks are tested with more depth (Based on interview)	OK
1.A.3	A technique for test specification is used.	OK
1.A.4	A motivated choice is made if the whole product should be re-tested or just the sub system that have been modified. (Based on interview)	OK
1	**Test strategy Product B**	**OK**
1.A	*Test strategy for single high-level test*	
1.A.1	A risk analysis is made. (Based on interview)	OK
1.A.2	Subsystems with high risks are partly tested with more depth but are not based on the risk analysis. (Based on interview)	OK
1.A.3	An informal technique for test specification exists, but it is not documented. (Based on interview)	OK
1.A.4	A motivated choice is made if the whole product should be re-tested or just the sub system that have been modified. (Based on interview)	OK
1	**Test strategy Product C**	**OK**
1.A	*Test strategy for single high-level test*	
1.A.1	A risk analysis is made. (Based on interview)	OK
1.A.2	Subsystems with high risks are partly tested with more depth but are not based on the risk analysis. (Based on interview)	OK
1.A.3	An informal technique for test specification exists, but it is not documented. (Based on interview)	OK
1.A.4	A motivated choice is made if the whole product should be re-tested or just the sub system that have been modified. (Based on interview)	OK

Table 6.2: Key area 2: Life-Cycle Model

Nr.	**Key Area** / *Level* / Checkpoint	
2	**Life-cycle model**	
2.A	*Planning, Specification, Execution*	
2.A.1	For the test (at least) the following phases are recognized: planning, specification, and execution. These are subsequently performed, possibly per subsystem. A certain overlap between the phases is allowed.	
2.A.2	Activities to be performed per phase are:	
2.A.2.1	formulate assignment, determine the test basis, determine test strategy, set up organization, set up test deliverables, define infrastructure and tools, set up management, determine planning, produce test plan (phase Planning);	
2.A.2.2	design test cases and test scripts, specify intake of test object and infrastructure, realize test infrastructure (phase Specification);	
2.A.2.3	take in test object and infrastructure, set up starting test databases, execute (re)tests (phase Execution).	
2	**Life-cycle model Product A**	**OK**
2.A	*Planning, Specification, Execution*	
2.A.1	Since all three phases (Planning, Specification and execution) exists this checkpoint is achieved.	OK
2.A.2	Activities to be performed per phase are:	
2.A.2.1	The documents Test plan and Test Survey do not contain any information about planning and organization however the responsible tester claims that the information exists in another document.	OK
2.A.2.2	Test cases are defined in System test case document.	OK
2.A.2.3	The test bed and test object is set up and the test result of the execution is located in the documents Type Test Record and the system test status report.	OK
2	**Life-cycle model Product B**	**OK**
2.A	*Planning, Specification, Execution*	
2.A.1	Since all three phases (Planning, Specification and execution) exists this checkpoint is achieved.	OK
2.A.2	Activities to be performed per phase are:	
2.A.2.1	Test plan do not contain any information about planning and organization (allocate personnel and responsibilities), however this information are located in the Project plan. (Based on interview)	OK
2.A.2.2	Test cases are defined in Type test description document.	OK
2.A.2.3	The test bed and test object is set up and the test result of the execution is located in the Type Test Record.	OK
2	**Life-cycle model Product C**	**NO**
2.A	*Planning, Specification, Execution*	
2.A.1	All three phases (Planning, Specification and execution) exists this checkpoint is achieved.	OK
2.A.2	Activities to be performed per phase are:	
2.A.2.1	No test plan could be found but according to the responsible tester some of the information exists in another document. (Based on interview)	NO
2.A.2.2	Test cases are defined in Type test description document.	OK
2.A.2.3	The test bed and test object is set up and the test result of the execution is located in the Type Test Record.	OK

Table 2.3: Key area 5: Test Specification Techniques

Nr.	**Key Area** / *Level* / Checkpoint	
5	**Test specification techniques**	
5.A	*Informal techniques*	
5.A.1	The test cases are defined according to a documented technique.	
5.A.2	The technique at least consists of: a) start situation, b) change process = test actions to be performed, c) expected end result.	
5	**Test specification techniques Product A**	**OK**
5.A	*Informal techniques*	
5.A.1	Test specification technique is located in the System Test Plan but the document is old, from 2001.	OK
5.A.2	The technique consist of start situation, test actions to be performed and expected end result.	OK
5	**Test specification techniques Product B**	**NO**
5.A	*Informal techniques*	
5.A.1	The test cases are defined to a test specification technique but it is not documented.	NO
5.A.2	Since there is no documented process this checkpoint cannot be fulfilled.	NO
5	**Test specification techniques Product C**	**NO**
5.A	*Informal techniques*	
5.A.1	The test cases are defined to a test specification technique but it is not documented.	NO
5.A.2	Since there is no documented process this checkpoint cannot be fulfilled.	NO

Table 6.4: Key area 11: Commitment and Motivation

Nr.	**Key Area** / *Level* / Checkpoint	
11	**Commitment and motivation**	
11.A	*Assignment of budget and time*	
11.A.1	Testing is regarded by personnel involved as necessary and important.	
11.A.2	An amount of time and budget is allocated to testing.	
11.A.3	Management controls testing based on time and money. A feature is that if the test time or budget is exceeded, initially a solution is sought within the testing (doing overtime or employing extra people when exceeding these limits or on the contrary cutting time and/or budget.	
11.A.4	In the team there is enough knowledge and experience in the field of testing.	
11.A.5	The activities for testing are full-time for most participants (therefore there are not many conflicts with other activities).	
11.A.6	There is a good relationship between the testers and other disciplines in the project and the organization.	
11	**Commitment and motivation Product A**	**OK**
11.A	*Assignment of budget and time*	
11.A.1	The testing is regarded as important. (Based on interview)	OK
11.A.2	Project has time and budget allocated for testing. (Based on interview)	OK
11.A.3	Test time and budget is extended when exceeding time or budget. (Based on interview)	OK
11.A.4	Within the test team there are enough knowledge about testing but more people need general knowledge about testing. (Based on interview)	OK
11.A.5	The person who performs the tests does not get disturbed by other activities. (Based on interview)	OK
11.A.6	The relationship between the testers and other disciplines are good. (Based on interview)	OK
11	**Commitment and motivation Product B**	**NO**
11.A	*Assignment of budget and time*	
11.A.1	Testing is regarded as important. (Based on interview)	OK
11.A.2	Project has time and budget allocated for testing. (Based on interview)	OK
11.A.3	Test time and budget is extended when exceeding time or budget. (Based on interview)	OK
11.A.4	The person who performs the tests often lack general knowledge about testing and also lack knowledge about the product. (Based on interview)	NO
11.A.5	The testers could have conflicts with other activities. (Based on interview)	NO
11.A.6	The relationship between the testers and other disciplines are good. (Based on interview)	OK
11	**Commitment and motivation Product C**	**NO**
11.A	*Assignment of budget and time*	
11.A.1	Testing is regarded as important and necessary by the personnel. (Based on interview)	OK
11.A.2	Time and budget is allocated to testing. (Based on interview)	OK
11.A.3	Test time and budget is extended when exceeding time or budget. (Based on interview)	OK
11.A.4	The person who writes the test cases often lack knowledge about testing. (Based on interview)	NO
11.A.5	Sometimes the participants get disturbed by other activities. (Based on interview)	NO
11.A.6	The relationship between the testers and other disciplines are good. (Based on interview)	OK

Table 6.5: Key area 15: Reporting

Nr.	**Key Area** / *Level* / Checkpoint	
15	**Reporting**	
15.A	*Defects*	
15.A.1	The defects found are reported periodically, divided into solved and unsolved defects.	
15	**Reporting Product A**	**OK**
15.A	*Defects*	
15.A.1	The defects are reported periodically, and divided into solved and unsolved. (Based on interview)	OK
15	**Reporting Product B**	**NO**
15.A	*Defects*	
15.A.1	The defects found are only reported when it is needed. (Based on interview)	NO
15	**Reporting Product C**	**NO**
15.A	*Defects*	
15.A.1	The defects found are only reported when it is needed. (Based on interview)	NO

Table 6.6: Key area 16 Defect Management

Nr.	**Key Area** / *Level* / Checkpoint	
16	**Defect management**	
16.A	*Internal defect management*	
16.A.1	The different stages of the life cycle of the findings are administrated (up to and including retest).	
16.A.2	The following items of the finding are registered:	
16.A.2.1	- unique number	
16.A.2.2	- person entering the defect	
16.A.2.3	- date	
16.A.2.4	- seriousness category	
16.A.2.5	- problem description	
16.A.2.6	- status indication	
16	**Defect management Product A**	**OK**
16.A	*Internal defect management*	
16.A.1	The life cycle from finding a defect up until re-test is administrated. (Based on interview)	OK
16.A.2	The following items of the finding are registered:	
16.A.2.1	The ID of the defect is located in System Test Status Report	OK
16.A.2.2	The name of the person entering the defect are located in System Test Record	OK
16.A.2.3	The date are located in System Test Status Report	OK
16.A.2.4	The seriousness of the defect are located in System Test Status Report.	OK
16.A.2.5	The problem description of the defect is located In System Test Status Report.	OK
16.A.2.6	The status of the defect is located in System Test Status Report.	OK
16	**Defect management Product B**	**NO**
16.A	*Internal defect management*	
16.A.1	The life cycle from finding a defect up until re-test is administrated. (Based on interview)	OK
16.A.2	The following items of the finding are registered:	
16.A.2.1	The findings of defects are identified by the test ID located in type test record	OK
16.A.2.2	Person entering the defect located in type test record	OK
16.A.2.3	Date of the defect located in type test record	OK
16.A.2.4	Seriousness category are not located in type test record	NO
16.A.2.5	Problem description are located in type test record	OK
16.A.2.6	Status of the defect are not located in type test record	NO
16	**Defect management Product C**	**NO**
16.A	*Internal defect management*	
16.A.1	The life cycle from finding a defect up until re-test is administrated. (Based on interview)	OK
16.A.2	The following items of the finding are registered:	
16.A.2.1	The findings of defects are identified by the test ID located in type test record	OK
16.A.2.2	Person entering the defect located in type test record	OK
16.A.2.3	Date of the defect located in type test record	OK
16.A.2.4	Seriousness category are not located in type test record	NO

16.A.2.5	Problem description are located in type test record	OK
16.A.2.6	Status of the defect are not located in type test record	NO

Table 6.7: Key area 18: Test Process Management

Nr.	**Key Area** / *Level* / Checkpoint	
18	**Test process management**	
18.A	*Planning and execution*	
18.A.1	Prior to the actual test activities a test plan is formulated in which all activities to be performed are mentioned. For each activity there is an indication of the period in which it runs, the resources (people or means) required and the products to be delivered.	
18	**Test process management Product A**	**OK**
18.A	*Planning and execution*	
18.A.1	Activities that are to be performed exist in the documents Type Test Plan and Test Survey but no information can be found regarding the period each activity it will run and which people will be responsible. However according to interview with the responsible tester the information could be found in project plan. (Based on interview)	OK
18	**Test process management Product B**	**OK**
18.A	*Planning and execution*	
18.A.1	Activities that are to be performed exist in the Type Test plan but no information can be found regarding the period each activity it will run and which people will be responsible, however this information are located in the Project plan. (Based on interview)	OK
18	**Test process management Product C**	**NO**
18.A	*Planning and execution*	
18.A.1	Since the test plan was not found but according to interview with the responsible tester some of the information are located in another document. (Based on interview)	NO

5. TPI Assessment Summary

The outcome of the TPI assessment is presented in Table 7.1 of 21 key areas were approved and the reason for not more key areas are fulfilled is that the TPI checkpoints are specific when describing what needs to be fulfilled to get approved.

Table 7.1 Result of the TPI Assessment

	Product A	**Product B**	**Product C**
Test strategy	Fulfilled	Fulfilled	Fulfilled
Life-cycle model	Fulfilled	Fulfilled	Not fulfilled
Test specification techniques	Fulfilled	Not fulfilled	Not fulfilled
Commitment and motivation	Fulfilled	Not fulfilled	Not fulfilled
Reporting	Fulfilled	Not fulfilled	Not fulfilled
Defect management	Fulfilled	Not fulfilled	Not fulfilled
Test process management	Fulfilled	Fulfilled	Not fulfilled
Total fulfilled	7 / 7	3 / 7	1 / 7

RESULT AND DISCUSSION

The first goal in this section was to do an assessment of the current test process at The Company. The framework used was TPI and the assessment showed that the current maturity of the test process at The Company is at low maturity for Product B and product C, Product A did pass the first seven key areas of the TPI model. Some of the key areas that are not fulfilled for Product B and Product C only require small adjustments to be approved.

To increase the maturity of the test process it can be good to introduce a test process improvement model as a reference model, for example the TPI model.

Next goal in this section was to identify improvement suggestions of the current test processes. None of the identified improvement suggestions are suitable for further investigation for the last part in this thesis. After consulting with responsible people at The Company, test automation of the HMI was chosen to investigate further. Test automation is an interesting area for The Company to get more knowledge about since testing of the HMI at The Company needs to be improved.

This assessment was done by interviewing the responsible testers and analysis of test documents for the products. The assessment was limited to a group of people and documents. To make a more complete TPI assessment more people and documents need to be available, more time for the assessment is also required.

CONCLUSION

The TPI assessment and analyze of the current test processes resulted in the following improvement suggestions:

The Document names and the information in the test documents differ for each of the products. In order to reach an equivalent test process a standard for the documents is needed. This can be done by following guidelines TPI provide or some other standard for test document description like IEEE 829-2008, we refer [3].

Defect Management Life Cycle differs for the products and needs to be a defined documented process that is equal for each product. TPI and TMAP provide some information of what the process should look like. A defined defect management life-cycle will help to get more control of the process and it will also be a good source for collecting metrics and trace quality improvements over time, see Pol et al (2002).

Defect Management System to monitor the current status of reported defects. The system should be suitable for all the products. During the interviews responsible testers said that a defect management system suitable for their needs is desired. A suitable defect management system is important to implement according to the literature, we refer Koolman and Pol (1999) and since one of the goal for The Company is to get to a situation where all products following the same test process the system should be suitable for all products.

Education of the testers is important. In TPI it is considered to be a requirement that the test team have enough of knowledge about testing. During interview with responsible tester for Product C they lack general knowledge of testing in the team. Educations of the testers that lack knowledge about testing are therefore recommended.

Test Cases for Product B and Product C are not based on the risks. The reason for this can be both or one of the two reasons:

i. Test case designers need more knowledge of the product risks

ii. Risk analysis needs more focus on the product risks.

However, the reasons are only an assumption since the risk documents were not analyzed we could not determine which one of the above assumptions is correct or even if neither one of them are correct. Some subsystems with higher risks are tested with more depth but this could not be derived from the risk analysis according to interviews. To be sure of that the test cases are designed with a suitable depth depending on the risk of the subsystem the test cases should be based on the risks, see Koolman and Pol (1999).

Test Specification Technique for product B and Product C exist, but only one informal test specification technique exists which are not documented. Several test specifications techniques have to be documented and used by the test case designer to reach the required depth of the test that different subsystem requires. Several test specification techniques are described in Pol et al (2002).

Test Plan According to several sources [1, 3, 5, 18] the test plan should contain information about responsibilities, activities and in which period they are to be executed. Product C does not even have a test plan, the other two products does not have planning and allocation of personnel in the test plan but if there are a reason to have this in another document it would be ok to have it there but it should be references to that document from the test plan. The reason for this is the test plan should contain all information that about everything about the test process or references where information can be found. It is also good to follow one standard for the test plan that can be used for all products so that The Company’s goal can be achieved which are that all products should follow the same test process. It will also be easier for new people to learn and understand the test process.

Low Level Testing is partly implemented on the Product A but is in need of further development. Product B and Product C have not implemented unit testing and should investigate how it can be implemented on those products. The reason to introduce low level testing is to catch errors earlier in the development. It is cheaper to correct errors in the early stage of development than correct errors late in the development, see for more details Koolman and Pol (1999). This can be done by following test specification techniques that are suitable for unit test which can be found in literature; for more details we refer Koolman and Pol (1999) and Pol et al (2002).

ACKNWLEDGEMENTS.

The present paper is an integral part of the project work entitled "Project Assessment Using Test Maturity Model Integration(TMMi)"; submitted in partial fulfillment for the award of Bachelor of Engineering in Computer Science and Engineering of Visvesvaraya Technological University, Belgaum, India during the academic year 2012-13.The last three authors of this paper would like to express their immense gratitude to Dr. Puttamadappa C., Principal,Sapthagiri College of Engineering Bangalore, Dr. C.M. Prashanth, Professor & Head, Department of Computer Science and Engineering,Sapthagiri College of Engineering, Bangalore for his help and inspiration during the tenure of the B.Tech. Program. The last three authors would also like to express their heartiest gratitude to their sincere Guide Prof. (Dr.) V.N. Maurya, School of Science & Technology, The University of Fiji, Saweni, Fiji& Ex Director, Vision Institute of Technology, Aligarh (G.B. Technical University, Lucknow, India) and Co-Guides Mrs. Poornima G.J., Assistant Professor of Department of Computer Science & Engineering, Sapthagiri College of Engineering, Bangalore and Er. Avadhesh Kumar Maurya, Assistant Professor & Head, Department of Electronics & Communication Engineering, Lucknow Institute of Technology (G.B. Technical University, Lucknow) for their valuable advice, sincere guidance and r egular assistance throughout the project work.

REFERENCES

[1] Ericson, Thomas, Subotic, Anders and Ursing, Stig. TIM - A test improvement model.

[2] Fewster, Mark and Graham, Dorothy, Software test automation effective use of test execution tools. Harlow : Addison-Wesley, 0-201-33140-3, **1999**.

[3] IEEE Std 829-**2008**. [Online] 01 14, **2010**. http://ieeexplore.ieee.org/Xplore/login.jsp?url=http%3A%2F%2Fieeexplore.ieee.org%2Fstamp%2Fstamp.jsp%3Ftp%3D%26arnumber%3D4578383%26isnumber%3D4578382&authDecision=-203.

[4] Karlström, Daniel, Runeson, Per and Nordén, Sara. A minimal test practise framework for emerging software organisations (MTPF).

[5]Koomen, Tim and Pol, Martin. *Test Process Improvement A step-by-step guide to structured testing*. s.l. : Addison Wesley, **1999**.

[6]Koroorian, Saam and Kajko-Mattsson, Mira, A tale of two daily build projects. s.l. : IEEE, 978-0-7695-3372-8, **2008**.

[7]Koskela, Lasse, Introduction to code coverage, Javaranch, **2004** [Online] http://www.javaranch.com/journal/2004/01/IntroToCodeCoverage.html.

[8]Maurya V.N., Bathla R.K., Maurya A.K. & Arora D.K., A dynamic innovative scenario of automated regression testing using software testing tool, International Journal of Information Technology and Operations Management, Academic and Scientific Publishing, New York, USA, Vol. 1, No.1, pp. 1-10, **2013**. ISSN: 2328-8582

[9]Maurya V.N., Bathla R.K., Maurya A.K., Arora D.K. & Gautam R.A., An alternate efficient sorting algorithm applicable for classification of versatile data, International Journal of

Mathematical Modeling and Applied Computing, Academic & Scientific Publishing, New York, USA, Vol.1, No. 1, pp. 1-10, **2013**.

[10] Maurya V.N. & Bathla R.K., Design and Analytical Study of Module Testing, Ph.D. Thesis, Department of Computer Science & Engineering, CMJ University, Shillong, Meghalaya, India, **2012**.

[11] Persson, Christer and Yilmaztürk, Nur. *Establishment of Automated Regression Testing at ABB: Industrial Experience Report on 'Avoiding the Pitfalls'.* s.l. : IEEE, **2004**.

[12] Pol, Martin, Teunissen, Ruud and Van Veenendaal, Erik. *TMAP, Software Testing.* **2002**. 0-201-74571-2.

[13] Rajender Kumar, Maurya V.N. & Maurya A.K., A cost- benefit model for evaluating regression testing technique, International Journal of Software Engineering & Computing, Serials Publications, New Delhi, India, Vol.4, No. 2, pp. 84-89, **2012**. ISSN: 2229-7413

[14] Ramler, Rudolf and Wolfmaier, Klaus. *Economic Perspective in Test Automation: Balancing Automated and Manual Testing with Opportunity Cost.* Hagenberg : ACM, **2006**.

[15] Sebesta Robert W., Programming the World Wide Web, Pearson Education, 4th Edition, **2008**.

[16] Stefan, Berner, Roland, Weber and Rudolf, Keller. *Observations and Lesson Learned from Automated Testing.* s.l. : ACM, **2005**.

[17] Veenendaal Van Erik , TMMi Release 1.0, TMMi Foundation, **2012**

[18] Veenendaal, Erik van. Test Maturity Model Integration (TMMI) Version 2.0. s.l. : TMMi Foundation, **2009**.

[19] Westin, Fredrik et al, Lesson learned from attempts to implement daily Build. s.l. : IEEE, 1534-5351/07,**2007**