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Improving Test Automation Process by Sharing Knowledge between Sites

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Preface

This study has been a rewarding learning experience for me as it provided me with the opportunity to get an insight of the realistic and practical challenges faced by multinational companies in collaborating knowledge sharing efforts. It has been very challenging and interesting at the same time to know various people across the globe with different cultures and working together with them. I would like to take this opportunity to thank each and every one who supported me directly and indirectly during the writing of this thesis.

I would like to thank everyone at the case company who contributed to this study and came forward with all their innovative ideas and suggestions to make this study successful.

Special thanks to my instructor Dr. Marjatta Huhta and Zinaida Grabovskaia, PhL, for their continuous encouragement, guidelines and motivation during my writing this study. I would like to thank all other teachers at the school as well who provided me with feedback and suggestions to add value to this study. Finally, I am also thankful to many of the classmates who contributed to this study with their meaningful advice.

At the end, I would like to thank my family and friends as without their support it would not have been possible to complete this study. I would like to say thanks to my dear husband for being encouraging and supportive throughout this study. Many thanks to him for spending several sleepless nights with me to assist me in finishing this study successfully. Last but not least, my lovely children were a great source of inspiration to finishing this study on time. Super thanks to them for their sacrifice of favourite bed time stories many times and allowing me to invest that time in writing this thesis during nights.

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This study aims to propose a road map for improving the test automation process of the scattered sites of a global medical device manufacturer by sharing knowledge between the sites. Currently, the case company has very specialized and valuable skill sets but the knowledge set is scattered across the globe and cannot be utilized by other sites due to the lack of knowledge sharing activities between the sites. Hence, the case company needs a system in place to exchange knowledge and skill sets of the automation sites to address the knowledge need faced by the automation sites.

The research approach used for this study is case study. The research data was collected by conducting discussion interviews with automation specialists of five automation sites for making a current state analysis. A proposal for the study was drafted based on a literature review, current state analysis and suggestions from key automation representatives of the sites. The proposal was then validated with the stakeholders of the automation sites to finalize the proposal based on the feedback collected from stakeholder discussions.

This study proposes a road map for a centralized knowledge management system (KMS) to collaborate knowledge sharing activities between the sites for improving the existing test automation process in practice. The proposed KMS facilitates knowledge sharing collaboration between the sites for reutilizing the existing test automation knowledge of other sites. Moreover, it also helps to reduce the waiting time to fix the issues which concern the expertise of other sites. Hence the proposed KMS will eventually improve the quality as well as velocity of service of test automation sites.

Key words	Test Automation, Validation and Verification Testing, Test Automation Process, Knowledge Management

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1 Introduction

This study focuses on internal knowledge sharing opportunities between geographically scattered automation sites of a multinational medical device manufacturer to cater the knowledge need faced by each site. The case company has vast existing knowledge in several areas of test automation which is scattered across several sites and it is hard to capture and reutilize the existing knowledge by other units of the case company. Internal knowledge sharing between the automation sites could be helpful in creating a common technical knowledge base for the automation department due to increased collaboration between the sites. Moreover, such cross functional resource pool with complementary skill sets could unveil the opportunities to add value for the whole department. By collaborating the automation effort of many sites, an improved automation process can help in developing the high quality automation tests suitable for testing the end-to-end product package. Thus, the idea of knowledge sharing for the improvement of the automation process across the sites of the case company will eventually enhance the quality of deliverables and bring down the maintenance and implementation effort for the automation department of the organization.

1.1 Case Company Background

The case company is a global medical device manufacturer based in the United States producing specialized high technology medical devices. The products by the case company are currently in demand by customers across Europe and US region. The case company has development centers in North America, Europe, and Asia along with around 70 sales and support offices across the world. It has a total man power of over 5,500 people who work at different geographical locations globally. In fiscal year 2013, the case company has shown a total $2.6 billion turnover reporting an increase of 5% in total revenues over fiscal year 2012.

At present the case company is a market leader driven by product quality and product variety in this market segment. The case company addresses the customer need to manufacture high quality error free product as the devices deal with welfare of human being. Since the case company is a global medical device manufacturer, each development center of the case company manufactures a part of the medical device which needs very specialized knowledge base and skill sets to manufacture the part. The product components manufactured by the development units are then packaged together to sell it to customers. Each development site also has its own test automation department which deals with validation and verification of the manufactured part of the

device. Thus, each test automation department uses its own process and tools which are highly dependent on a very specific technical and functional knowledge base related to that particular part of the medical device.

The Automation Departments in the case company implement Test Automation projects for the verification & validation of the product component through the test automation process and automation tools in use.

1.2 Key Terms in This Study

Test Automation is an automation tool based testing process for the verification and validation of the product where test execution is done automatically by simulated virtual users without manual intervention and the actual outcomes of the tests are validated automatically against the expected output of the tests to mark the tests as passed or failed.

GUI Based Automation is a test automation process where test execution is done automatically on the graphical user interface of the application by simulated virtual users without manual intervention. *API Based Automation* is a test automation process where test execution is done automatically on the product code base of the application by simulated virtual users without manual intervention. *Unit Test Automation* is a test automation process where test execution is done automatically on a particular unit of the product code base of the application by simulated virtual users without manual intervention

Validation is a testing process which assures that the product or service meets customer or external user needs whereas *Verification* is the testing process which assures that every part of the product or service satisfies the specification or requirements.

Knowledge Management is an upcoming concept to facilitate knowledge related activity in an organization to foster knowledge sharing collaboration between teams, units, departments or scattered sites.

Test Automation Process is a well-defined life cycle or process model within the organization which starts from gathering testing requirements; test planning, test designing, test implementing and validating the desired output results of the test automation department.

1.3 Business Challenge

The main business challenge is related to a lack of collaboration in test automation activities between the different automation sites of the case company as each site uses their own test automation process and automation tool suiting to their needs. This lack of collaboration, in turn, results in a lack of knowledge sharing between the automation sites. Hence, this localized approach causes redundant and duplicate tasks as well as increased workloads for each site. It is visible in the following problems:

First of all, lack of knowledge sharing between automation sites increases the work load as each site validates interdependent product components. The automation sites require domain knowledge of product components manufactured by other sites for the integration testing of product components. Thus, the lack of collaboration in test automation activities is thereby a major concern for the end to end validation of the products package.

Secondly, each development site uses its own automation process and tools suitable for its needs. These tools are used for the automated verification of the product component manufactured by that development center. Each automation tool used in the organization costs heavily in terms of license costs. Moreover, the license servers for the automation tools are maintained at a remote location from the location where the tools are used. This results in both a time gap and a service gap during situations like license upgrades or tool related problems.

Finally, each automation tool and process needs to go through validation in order to comply with the FDA (US Food and Drug Administration) regulations and several other regulatory laws. This requires a lot of documentation to be maintained and updated during each release for audit purposes. Hence, the lack of collaboration in automation efforts results in redundant compliance related efforts for the automation department of the case company.

Thus, the lack of collaboration in the test automation activities between the automation sites eventually results in higher implementation and maintenance efforts for the case company.

1.4 Objective and Scope of the Study

The main objective of this study is to propose a roadmap for improving the test automation process by sharing knowledge and best practice between several automation sites located at multiple geographical locations in the case company.

The outcome of this study is a proposal for an improved test automation process for the automation sites of the case company to address the knowledge need and challenges of these sites. This improved process aims at improved speed, performance and efficiency of the test automation department as well as reduced implementation and maintenance efforts of the department in the long run.

The scope of the study includes the roadmap for the transition from the closed test automation approach to an open and collaborated test automation approach for the automation sites. It also provides action points to deal with the problems and issues faced while implementing the new improved test automation process for the automation sites.

This report is written in seven sections. Section 2 describes the design architecture of this study in terms of research approach, research design, data collection methodologies and reliability & validity check plan. Section 3 examines the current state of the case company and explores the existing best practice in the case company. It will also search for existing gaps in the current automation effort of the case company. Section 4 analyzes the existing knowledge and best practice from literature. Section 5 proposes a draft version of the proposal for a common test automation process for the case company. Section 6 examines the feedback from each contributing site on the draft proposal to make a final version of the proposal. Finally, Section 7 presents the summary and conclusion of this study, along with an evaluation of the study in terms of reliability, validity and success in achieving the objective.

2 Method and Material

This section focuses on research approach, research design, data collection methods and validity and reliability plan of this study.

2.1. Research Approach

This study is carried out as a case study since it deals with a contemporary phenomenon in the context of an organisation with embedded units. “A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between the phenomenon and the context are not clearly evident” (Yin 2003: 13-14). It gives the opportunity to the researcher “to explore individuals or organizations, simple or complex interventions, relationships, communities, or programs” (Yin, 2003). A case study supports the deconstruction and then subsequent reconstruction of the whole phenomenon for a complete understanding of the case (Yin 2003, 1994, 1-15).

A case study is also a form of qualitative research to explore, examine and describe a case or phenomenon using various data sources in the context of the study (Robson 2002:178). Collected data from each resource is then thoroughly analysed and converged in the context of the case study for understanding of the whole phenomenon. This convergence of data from multiple data sources strengthens the finding of the study on the one hand and on the other hand it makes the analysis more powerful and rich for a greater understanding of the whole case. (Baxter and Jack 2008: 554).

The type of case study for this thesis is case study with embedded units. A case study in an organisation with embedded units enables the researcher to explore the case while considering the influence of the various units in organisational decision making (Baxter and Jack 2008: 550). As described by Baxter and Jack (2008: 550), “the ability to look at sub-units that are situated within a larger case is powerful when you consider that data can be analysed within the subunits separately (within case analysis), between the different subunits (between case analysis), or across all of the subunits (cross-case analysis)”. This mode of analysis on the one hand leads to better illuminating the case but on the other hand there is a risk that data analysis revolves around the individual subunit level and fails to return to the global issue that they initially set out to address (Yin, 2003).

The case in this study is defined as “Test Automation Process” of the case company and this study examines the role of sharing knowledge between embedded automation units of the case company to improve the overall Test Automation Process of the company. In this study the data of several automation units of the case company is analysed separately and then the data is converged in the context of the research question of this study. The individual analysis of data from each automation units in this case helps to understand the influence of each automation unit in organizational decision making towards an improved automation process in the case company. Once the individual analysis of data is done to understand the gap and strengths of each unit, the data is then analysed with respect to other units to understand how knowledge sharing between the units can contribute towards an improved automation process in the case company.

2.2 Research Design

In order to develop an improved test automation process, it is important to understand the existing problems, concerns as well as best practice in use at various test automation departments of the case company which are located at different geographical loca-

tions. The research design of this study is developed to address these goals for improving the test automation process of the case company. The research design of the study is shown in Figure 1 below.

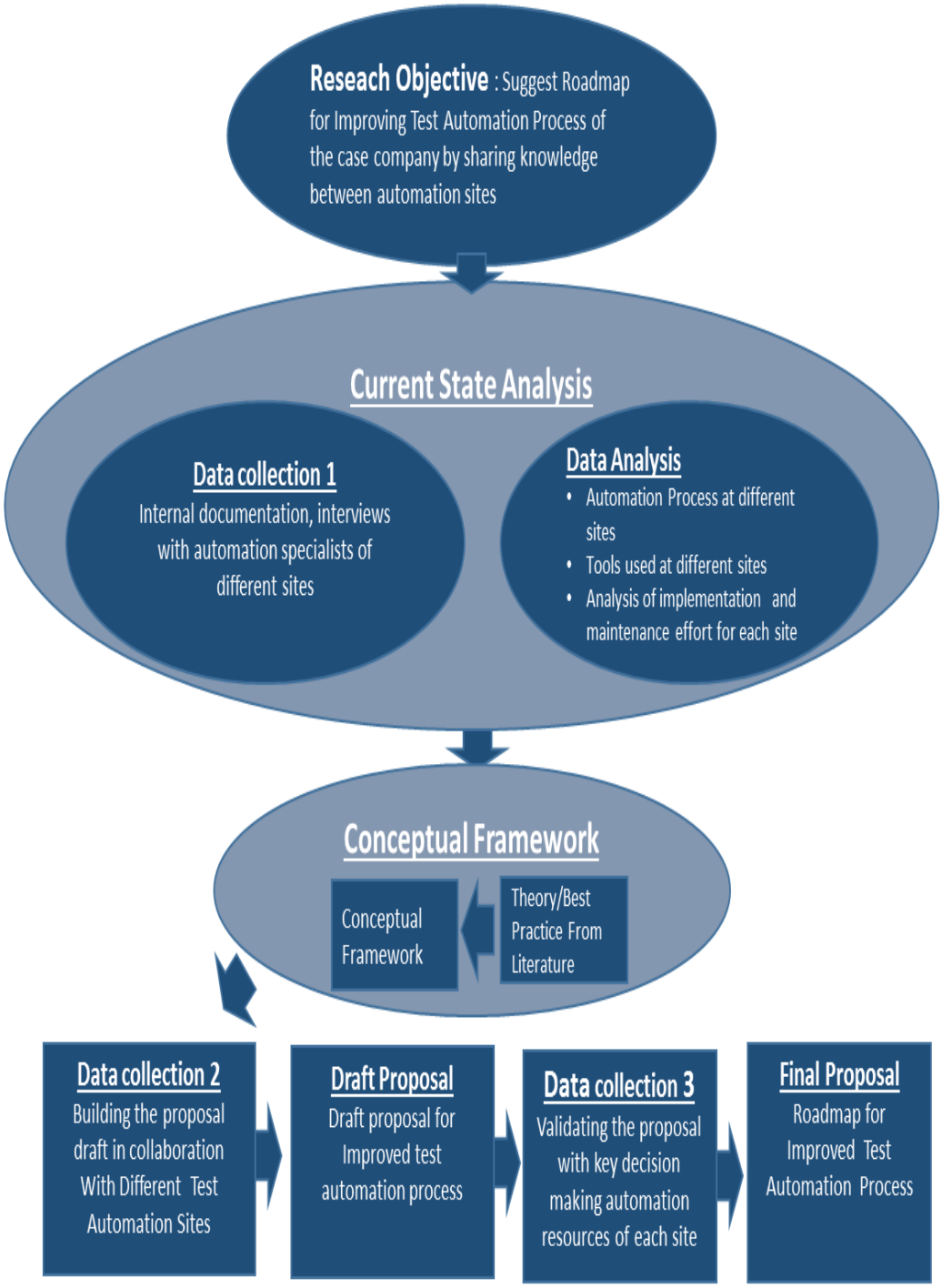

Figure 1. Research design of the study

As illustrated in Figure 1 above, this study analyzes the data for the current state analysis (Data 1) and then discusses the existing concepts and best practice from literature related to knowledge management between sites. A conceptual framework is then applied to design a draft proposal for an improved test automation process for the case company. It is done by integrating and collaborating specialized test automation knowledge of each site (Data 2).The draft proposal is then validated (Data 3) with all sites to verify if the draft proposal addresses their needs, concerns and acceptance criteria for each site. A final proposal for the improved test automation process is then designed considering all important feedback from the automation units.

2.3 Data Collection and Analysis Methods

Data for this study is collected from various data sources in order to strengthen the reliability of the study. Firstly, the current status of the test automation units of the case company was investigated by examining the internal documentation related to the test automation procedures and audit compliance documents of the test automation units. Secondly, series of interviews, meetings, video conferencing and discussions were organized with test automation specialists of the automation sites for in depth understanding of the current automation process in practice at each site. In addition to this, a second round of meetings and discussions with informants was organized during the design phase of the draft proposal so that the proposal addresses the concerns and challenges faced by each site. Finally, brain storming sessions using video conferencing and face to face meetings with key stakeholders of the test automation departments took place to validate the draft proposal in order to design the final proposal for the improved test automation process.

2.3.1 *Case Company Documentation*

Data related to the current test automation process, automation tasks and automation tools in practise is collected from *internal documentation* of the test automation departments of the case company, at various sites. These internal documents include:

First, the case company documents (related to existing processes and tools) are examined to understand test automation architecture, framework, and details of automation tools used by test automation departments. Second, the regulatory related documents to understand the regulatory and audit related specification for adopting a new tool and process. The details of this data collection are shown in Table 1 below.

Table 1. Internal Document List

Automation Unit	Documents	Description
Documents Applied by all Sites	• Regulatory Documents for FDA audits • Quality Assurance Document • Tool Validation Specification Medical Device Risk Management Document	• Testing specification and guidelines related to Quality Audits • Guidelines for tool validation • Risk Management guidelines
Site A	• Test Automation Architecture Document • Verification and Validation Document • Tool Validation procedure for Formal Testing	• Framework and Architecture used by automation department for the project • Product verification and validation tasks performed for the project • Tool validation process details to validate automation tools which can be used for formal testing.
Site B	• Software Verification and Validation Plan • Trace Matrix runs for Automated Test (Quality Centre) • Test Automation Framework Document • Testing Tool Validation Document • Backlog Items for product Validation	• Product verification and validation tasks performed for the project • Past Test result Data from quality Centre • Framework and Architecture used by automation department for the project • Tool validation process details to validate automation tools which can be used for formal testing. • Details of Task performed by automation resources
Site C	• Tool Validation Procedure • Trace matrix from QC • Test Automation Framework Document	• Product verification and validation tasks performed for the project • Past Test result Data from quality Centre • Framework and Architecture used by automation department for the project
Site D	• Verification and Validation plan • Tool validation for formal Testing • Test Architecture Document	• Product verification and validation tasks performed for the project • Tool validation process details to validate automation tools which can be used for formal testing. • Framework and Architecture used by automation department for the project

Site E	• Backlog Items for product Validation • Verification and validation plan document	• Details of Task performed by automation resources • Product verification and validation tasks performed for the project

As seen from table1 above, this thesis analyzes the best available documents from each site to secure adequate and explicit knowledge related to test Automation Framework, Test Architecture, Past test run data and Audit related specification of formal and informal testing of various automation units. These documents are investigated in order to understand the requirements and specifications for an improved automation process by sharing knowledge and best practice between sites.

2.3.2 *Interview Discussions*

Series of discussions, meetings and interviews were arranged with several automation specialists of the automation units in order to understand the existing gap as well as existing best practice with the automation process of each department. Data related to practical complications of the existing process, benefits related to the existing process and reasons for adopting the current approach were collected from each automation site which play an important role to develop a vision for the improved automation process for the case company

Faces to face meetings, video conferencing, and telephonic interviews are done with automation specialists, automation framework owner, automation leads and test automation managers to understand the existing automation process in place. The details of this data collection are shown in Table 2 below.

Table 2. Interview and Discussion Details

Data Collection Event	Participant	Topic	Duration	Date	Documentation
Interview (Video-Conferencing)	Test Automation Framework Owner (Site A)	• Understand Test Automation Framework of the unit • Process in practice for test automation in the unit • Automated Testing Tools in use and how it works in the unit • Possibility to collaborate the test automation efforts at various units of case company	1 hr. 20 min	23/01/2015	Field Notes
Interview (Video-Conferencing)	Test Automation Lead Test Automation Manager (Site B)	• Understand Test Automation Framework of the unit • Process in practice for test automation in the unit • Automated Testing Tools in use and how it works in the unit • Possibility to collaborate the test automation efforts at various units of case company • Possible bottlenecks in collaboration process	1 hr. 5 min	29/01/2015	Field Notes
Face to face Meeting	Test Automation Specialist (Site C) worked in collaboration with automation team of (Site B)	• Understand Test Automation Framework of the unit • Process in practice for test automation in the unit • Automated Testing Tools in use and how it works in the unit • Possibility to collabo-	1 hr. 10 min	30/01/2015	Field Notes

		rate the test automation efforts at various units of case company			
Face to face Meeting	Test Automation Lead (Site C)	• Understand Test Automation Framework of the unit • Process in practice for test automation in the unit • Automated Testing Tools in use and how it works in the units of case company	60 min	04/02/2015	Field Notes
Face to face Meeting	Test Automation Framework Owner (Site C)	• Automated Testing Tools in use and how it works in the unit • Possibility to collaborate the test automation efforts at various units of case company • Possible bottlenecks in collaboration process	1 hr. 10 min	11/02/2015	Field Notes
Interview (Video-Conferencing)	Test Automation Lead Test Automation Manager (Site D)	• Understand Test Automation Framework of the unit • Process in practice for test automation in the unit • Automated Testing Tools in use and how it works in the unit • Possibility to collaborate the test automation efforts at various units of case company	60 min	25/02/2015	Field Notes
Telephonic Interview	Test Automation Lead (Site E)	• Understand Test Automation Framework of the unit • Process in practice for test automation in the unit	35 min	26/02/2015	Field Notes

		• Automated Testing Tools in use and how it works in the unit • Possibility to collaborate the test automation efforts at various units of case company			

As seen from table 2 above, the analysis of the processes of each site is represented not only by written documentation but by consolidating the information of the personal interviews and reading internal process documentation of each site to understand the existing automation process in use. This data collection aims to establish what every site is doing in common as well as to examine what are the differences in the modality of the operations and process are between various automation departments.

2.4 Data Analysis

For the first round of data collection 1, interview discussions were organized with automation specialists of the automation sites based on the predefined questionnaire designed for the interviews with all automation sites. These questions were aimed to get a detailed understanding of the current state of the automation process and tools of each site. Appendix 1 at the end contains a sample interview questionnaire for the first round of data collection. The interviews were mostly discussion by nature beyond the limitations of a questionnaire but within the boundary of the research objective. Some sample field notes from these interview discussions are attached in appendix 1 section of this thesis for detailed understanding of the content of discussions.

After the first round of Data collection 1 from interview discussions and reading internal automation process documents, data of each automation sites was carefully analysed to make an *Automation Process Map* for each site. Key findings of each site were then further analysed to make a *Strength and Challenges* table for the sites. These strengths and challenges of each site were then grouped in five key categories such as issues related to Knowledge sharing, Product Domain Knowledge, Tool maintainability,

Test coverage and issues related to Test Framework and Test Architecture for each site.

Finally, a summary table was prepared to map the challenges faced by each site with the best practice from the other automation site addressing that particular key issue.

2.5 Validity and Reliability Plan

Validity and Reliability are two essential and mandatory prerequisite criteria for credibility of any good research. *Reliability* of a research refers to accuracy and correctness of the findings of the research. A research is reliable in terms of accuracy and correctness if the findings of the research are consistent in nature even if the research is carried out by a different researcher at some other point of time. Huhta (2013: 5) argued that if the study results are consistent over time as well as accurate in nature and reproduce similar results if carried out under a similar methodology, then the research is considered to be reliable. Thus, findings of a reliable study will always remain stable, repeatedly producible and time independent in nature (Kirk and Miller 1986: 41-42).

Validity of the research on the other hand concerns the degree to which a study succeeded in achieving the purpose of the study (Roberts et al 2006: 44). Validity directly refers to the closeness of the research finding with the initial research question for the study. The validity criteria of a study include accuracy and neutral interpretation of the collected data. Neutral Interpretation of data takes into consideration the perspective of study subject, population under study and informants linked with the research (Maxwell 1966). Thus, validity of research depends on data collection techniques and tools along with data analysis mechanism used to establish research findings. Moreover, long term association with the subject under study and close association with the informants also play a key role in the validity check of the data and data analysis during various stages of research (Baxter and Jack 2008: 556).

Validity and reliability are two interdependent terms where validity holds no value without reliability. The reliability of the study needs to be established to make this research valid (Lincoln and Guba 1985: 316). Since the proposed collaboration in the automation efforts of this study deals with the verification and validation of a medical device, the proposed process focuses on reliability criteria to make the proposal valid. Authenticity and trustworthiness of the findings is a must for this study as findings of this study

should be authentic and credible enough to withstand various safety audits including FDA as a medical device directly impacts the welfare of human life.

3 Current State Analysis

This section will give an overview of the test automation projects of the automation units of the development sites for verification and validation of the components of a medical device. It will briefly go through the current test automation process in use at each site to evaluate the existing gap as well as strength of each department in order to explore the opportunity of knowledge sharing between sites to address the challenges faced by the automation units. The background details of the test automation units are shown in Table 3 below.

Table 3. Development Units Overview

Development Sites	Location	Manpower	Overview
Site A	Europe	75	Test Automation unit involved in Test Automation projects for verification of product component manufactured by another development unit located in Europe.
Site B	Asia	150	Development unit involved in manufacturing multiple product components. Test automation unit is involved in automation projects intended for verification of product components manufactured by the site as well some of the component manufactured by USA unit
Site C	Europe	125	Development Unit with its own R&D centre. Test automation department is extensively involved in verification of product component manufactured by the Unit.

Site D	USA	250	Head office with own development centre manufacturing multiple component of the medical device used for end to end user workflow.
Site E	Canada	100	Development unit which manufactures standalone product. Test Automation Unit is involved in automation projects intended for verification of product manufactured by the site

As seen from table 3 above, the test automation units of the case company are located at various geographical locations across the globe. The automation units are extensively involved in automation projects intended for the verification of product components manufactured by the same development center or another development center. In the following section all the sites are going to be described based on the field notes of data collection 1.

3.1 Test Automation Department-Site A

Site A develops graphical user interface (GUI) based automated test suits to test the application using an automation tool built in house. This site develops test automation test suits for the product component manufactured by another development site located in some other country in the same time zone. The automation team and development team are located at a different geographical location but they are in good collaboration to decide together about product requirements needs to be automated for that product component. The test automation team creates regression tests as well as some integration tests intended for verification testing of the product component. The automation team then logs the test results to the report tracking tool which can be easily accessed by the actual product development Site. The test automation process map for Site A is shown in Figure 2 below.

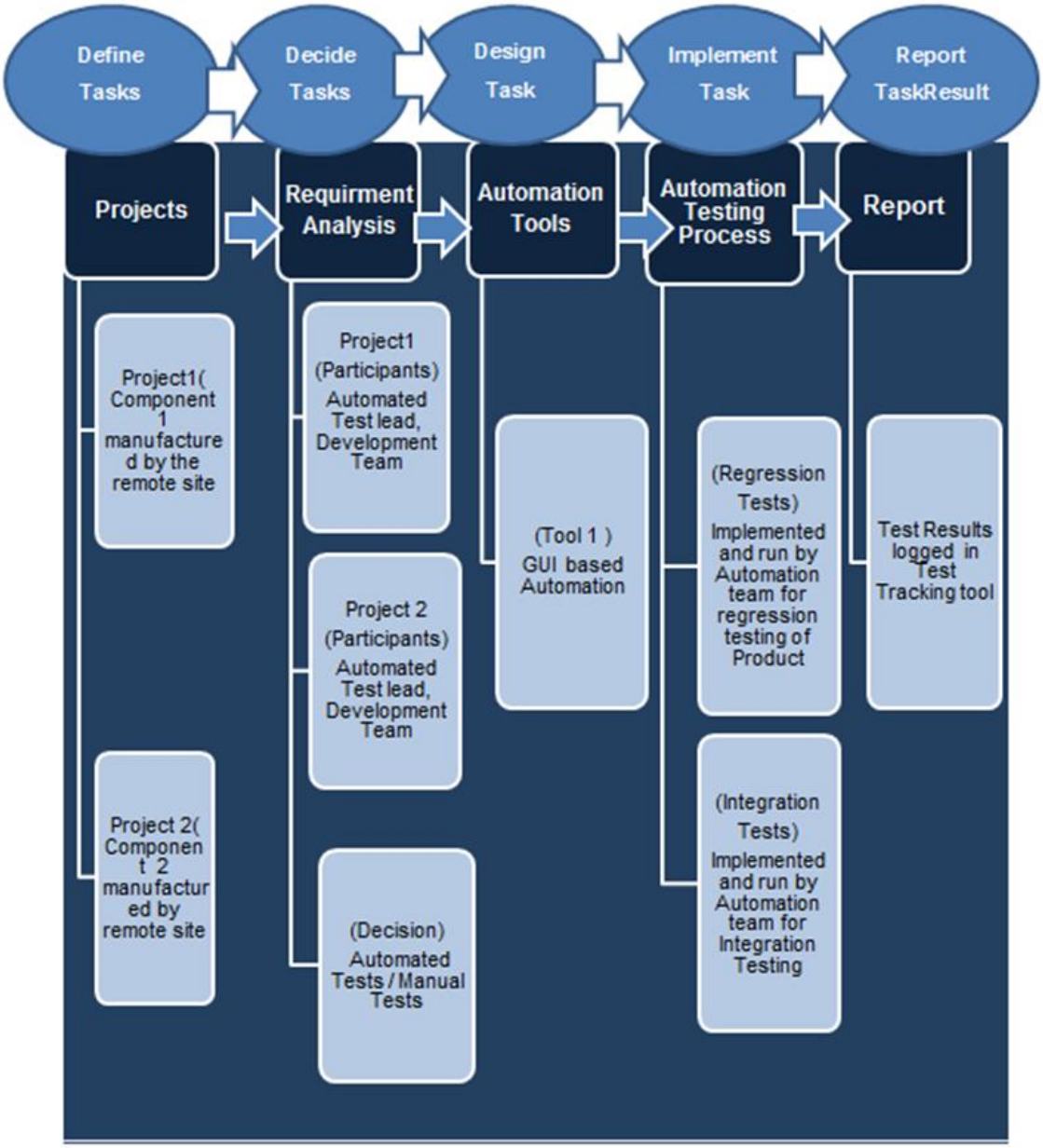

Figure 2. Test Automation Process Map-Site A

As illustrated in Figure 2 above, this automation site is involved in automation projects for the product component manufactured by another development center using a single automation tool and framework.

Key Findings and Analysis-Site A

The test automation team is dedicated to designing GUI based automation test suits to verify the product component. This site is not involved in code verification or unit testing of the product component.

The test automation team is located at a different geographical location than the development team; hence the automation team here is involved in lots of travels to development sites along with workshops, video conferencing and technical discussions for successful implementation of the test automation projects.

The test automation team uses the same automation tool to implement all the automation projects. This automation tool is stable by its nature and compatible with the objects of the product component. Some other test automation sites of the case company are evaluating the tool designed by this site for GUI based automation for their automation needs.

This automation site uses the similar technology and programming language as used to design the product component which makes the tests compatible with the product component without much of a hassle. Since the development site is located at a different geographical location, it is difficult to find minute details related to product implementation on a day to day basis. Hence, using similar technology as product development is also beneficial to fill the gap of domain knowledge for the product component.

This automation site is relatively new, hence it lacks in domain knowledge about core product components. A great deal of potential and knowledge base exists for automation testing at this site but it needs collaboration with another development sites to reduce automation efforts in integration testing as well as regression testing. A summary of the strengths and challenges of the automation department (Site A) is shown in Table 4 below.

Table 4: Strengths and Challenges-Site A

Key Issue	Strengths	Challenges
Knowledge Sharing		• Development team and Test automation team seats at two different geographical location • Lack of collaboration in test automation effort with other test automation sites
Product Domain Knowledge		• Lack of domain knowledge in core product components makes integration testing task challenging
Tool Maintainaibility	• Single stable automation tool which is easy to maintain and requires less documentation for audit purpose	
Test Coverage	• Skilled automation resources for GUI based automation	
Test Framework and Test Architecture	• Well designed and structured automated test architecture • Automation department uses same technology to design tests as product development team. Hence, test scripts are easy to maintain as well as stable and sustainable for long run	• Lack of formal documentation related to test architecture and automation testing framework

As seen from table 4 above, this test automation unit of the case company has strong automation skill sets as well as a stable automation framework but lacks product domain knowledge.

3.2 Test Automation Department-Site B

This test automation site is involved in GUI (graphical user interface) based automation projects for the product component manufactured by the site as well as for some other product components designed by other sites. This site is also involved in implementing an automation project related to an end to end installation process for a whole product package at customer sites. The test automation department does not follow any fixed process, architecture or automation tool for the automation projects as applications are complex and different from each other so no fixed approach works for all the projects. The automation site maintains its automation tool repository for functional testing of the product component. The automation team leads along with some automation specialists take a decision on selecting the product requirements which are suitable for automation. A pilot is done for each new product component to find the suitable tool for automating the particular product component. Formal and informal automated tests are designed for each product line and the results of the formal tests are logged in a report tracking tool. This site also implements a few performance testing projects using open source performance testing tools. The test automation process map for Site B is shown in Figure 3 below.

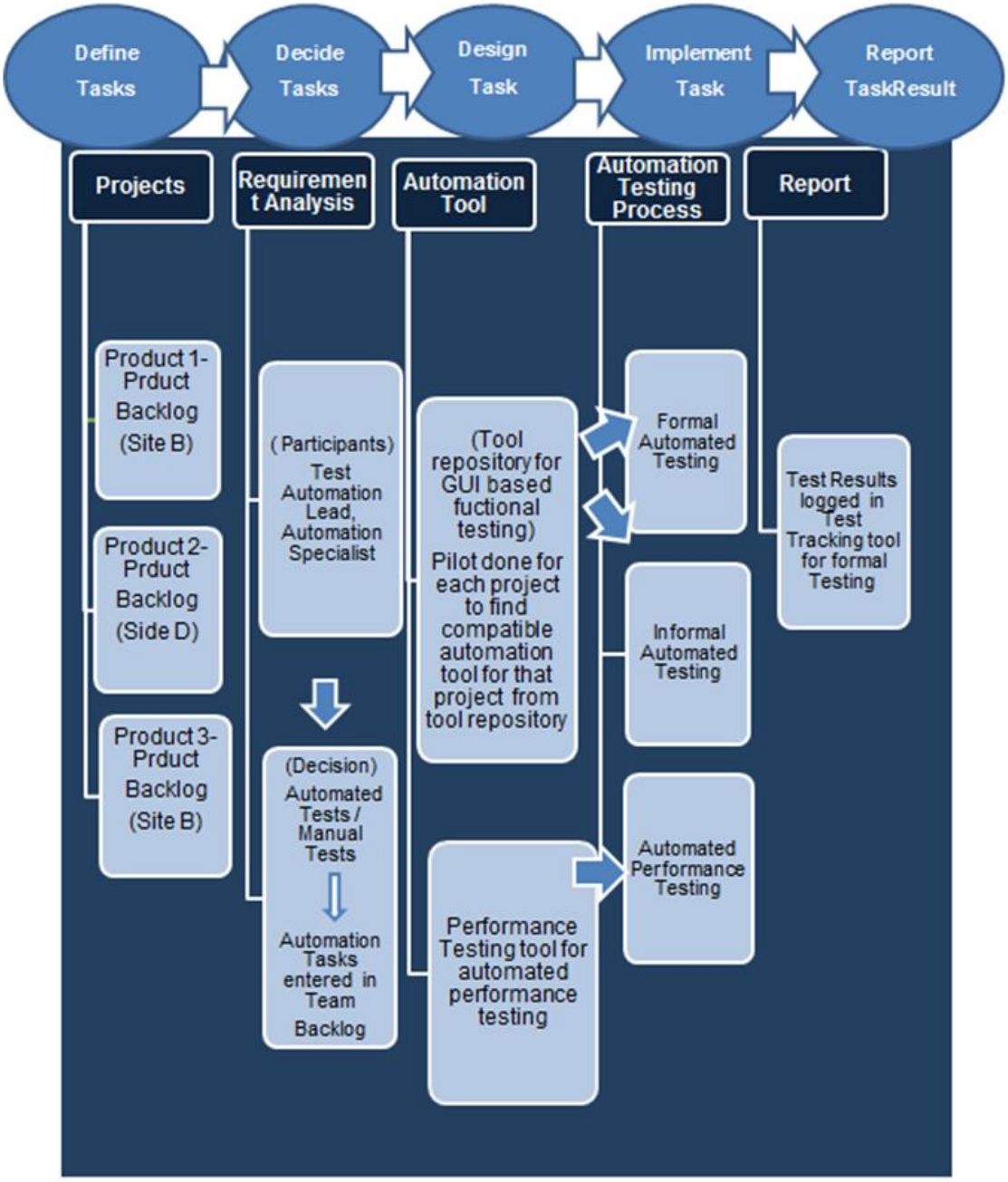

Figure 3. Test Automation Process Map-Site B

As illustrated in Figure 3 above, this automation site is involved in automation projects for product components manufactured by the same development center as well as product components manufactured by another development center using multiple automation tools and framework suiting that particular project.

Key Findings and Analysis-Site B

The test automation invests mostly in GUI based automation and no investment for white box automation. Hence, automated tests are used mainly for verification testing which does not cover the scope of unit testing. The performance testing team of the automation department is in a process of tool evaluation for a stable suitable licensed performance testing tool which will suit company need.

Good collaboration with the product development team makes the life of automation specialists easier. The product development team writes the code which makes the application objects easy to recognize by automation tools. At the same time the automation team does not have access to product codes which creates a barrier for implementing projects related to automated unit testing or verification testing.

The automation testing unit has a tool repository of automation tools compatible for functional testing. The tool repository includes some open source tools as well as some other licensed functional testing tools. These tools are validated for formal and informal testing based on intended uses of the tool. For every new project, a pilot is done to find the compatible tool to be used for test automation. Hence, this site has a good knowledge base about the automation tools compatible for application designed by various technologies. Since it is very difficult to test everything during the pilot, the automation team at times discovers very late that they have selected an incompatible tool from the tool repository.

This site lacks domain knowledge related to core product components as this development site is relatively new compared to the other development sites. Even though they have excellent skill sets related to automation tests, lack of core product domain knowledge makes the job of test automation specialists challenging during some automation projects. This lack of domain knowledge is also a reason for concern during the integration testing with the product components manufactured by other sites. A summary of the strengths and challenges of the automation department (Site B) is shown in Table 5 below.

Table 5. Strengths and Challenges-Site B

Key Issue	Strengths	Challenges
Knowledge Sharing		• Lack of collaboration in test automation effort with other test automation sites
Product Domain Knowledge	• Good collaboration between development team and test automation team. Product design is done in a way which is suitable for designing automated tests without much problem in object recognition.	• Lack of domain knowledge in core product components makes integration testing task challenging
Tool Maintainaibility	• Automation tool repository with validated automation tools suitable for automating variety of application manufactured using different technologies.	• Too much tool options create confusion at times. It results in selecting wrong tool from repository which at times discovered very late during the project • Redundant audit related documents due to several tools used in projects
Test Coverage	• Excellent Knowledge base for GUI based automation and compatible automation tools several product lines	• Redundant tasks due to similar formal and informal automated tests
Test Framework and Test Architecture	• Data driven automated tests which are easy to maintain and well structured	• Lack of formal documentation related to test architecture and automation testing framework

As seen from table 5 above, this test automation unit of the case company has strong automation skill sets, well-structured automation tests and specialized knowledge base for GUI based automation tools but lacks product domain knowledge.

3.3 Test Automation Department-Site C

This development site has a very strong automation unit involved in creating unit tests, regression test and reference tests. This automation site adopts a test driven approach for developing the product components. The test automation unit mostly adopts API based automation to test the product component codebase. The test automation unit is involved from the very beginning stage of the product development life cycle. The automation units design Unit test structures for the new requirement to be developed by this development center. Each developer uses these tests as the verification of their part of the code which is called unit testing. During the product development phase, automation specialists are involved in designing Regression tests for verification of the product component. Thousands of regression tests which include existing as well as new tests run overnight for verification of the product component once the product components are ready for testing. The test automation units also design reference data tests used to verify product component's results against previous release which helps the development unit if there are some major changes in the system outcome. The automation unit is also involved in some GUI (graphical user interface) based automation to automate some regression tests related to user workflows. The test automation process map for Site C is shown in Figure 4 below.

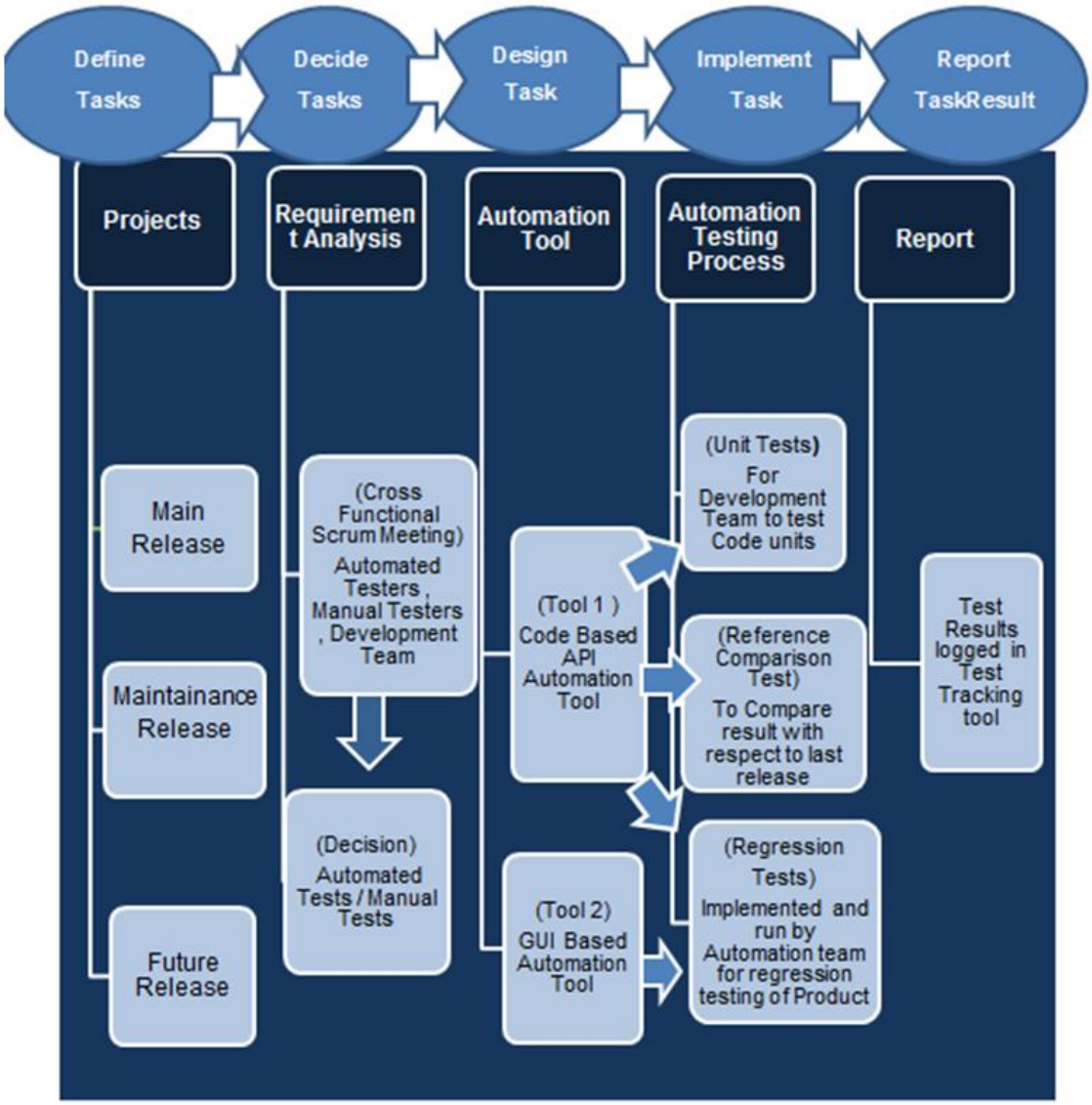

Figure 4. Test Automation Process Map-Site C

As illustrated in Figure 4 above, this automation site is involved in automation projects for the product component manufactured by the same development center using API based as well GUI based automation tool.

Key Findings and Analysis-Site C

This automation site invests much in API based white box (code based) testing and invests little in GUI based automation. Hence, the automation team is involved in mostly code based verification testing of product components without focusing much on GUI

based test automation.

Close collaboration between the development and test automation unit exists for this development center. This collaboration on the one hand helps in the early detection of the changes in product code as the automation specialists have direct access to the code. On the other hand cross functional teams including automation specialists, manual testers and development team for knowledge sharing play a key role in right decision making and successful implementation of the end to end product life cycle. However, when it comes to collaboration with other test automation sites a lack of collaboration with other sites exists. This at times results in a situation like unawareness of dropped feature at other sites which has a dependency on automated test workflows at this site.

The decision for selecting requirements for automated regression tests is made in collaboration with manual testers as well as the development team. This process makes a clear division of tasks between manual testers, automated testers and developers which removes the probability of overlapping and redundant tasks.

The test automation department adopts a product dominant strategy at par with the product development team for this site. The test suits are designed and implemented in a similar architecture like the product development department. Hence the test sets run for several development branches and release versions at the same time during nightly runs. The results of the automated tests are available each morning for checking.

The test automation department focuses least on the documentation of the test design architecture or automated testing process related document. Existing documents are insufficient to understand the implemented tests until digging every test and comments in the test scripts.

All the tools and technology used for the planning, designing and implementing the tests are well maintained and validated for the intended use. Hence, the automated tools satisfy the criteria of quality related standards and up to date for quality related audits.

Automated test structures are more people oriented than process oriented. Automated specialists are having long time ownership of the tests which results in tests being dependent on automation resources who know about the tests by heart. Since the automation framework is very old and outdated, it does not provide any guidelines for test design. Hence, each automation specialist implements tests in their own way which

makes automated test collection unstructured and difficult for another person to understand. A summary of the strengths and challenges of the automation department (Site C) is shown in Table 6 below.

Table 6. Strengths and Challenges-Site C

Key Issue	Strengths	Challenges
Knowledge Sharing	• Cross functional teams including automation specialist, manual testers and development team for knowledge sharing.	• Lack of collaboration in test automation effort with other test automation sites
Product Domain Knowledge	• Strong knowledge base for the product line with special skilled resources	• People oriented strategy - reason of concern in case of resources leaving the automation department.
Tool Maintainaibility	• Up to date tools and technology for quality related audits	
Test Coverage	• Extensive API based automated test suits which cover unit tests, regression tests and reference comparison tests. • Automated tests are used by several other departments in this site suiting different needs.	• Lack of GUI based automation
Test Framework and Test Architecture		• Outdated and complex Test Automation Framework which is difficult to maintain. • Lack of documentation for test automation architecture • No fixed strategy or guideline to design tests

As seen from the table 6 above, this test automation unit of the case company has strong product domain knowledge and in-depth API based automation coverage but lacks in terms of stable test architecture and framework.

3.4 Test Automation Department-Site D

This development site has a very strong automation unit which is responsible for managing the license server and automation testing tool license allocation to other automation sites. This automation unit is involved in designing GUI based automated tests for several product components at the same time. The intended uses of the automated tests designed by this site are to verify the functionality of product components through the user interface. Each Product development team has an automation lead dedicated for that particular product component. The test automation unit is involved from the very beginning stage of the product development life cycle. The development team and automation team sit together to decide on the requirements to be automated for informal and formal regression testing. The automation lead involved with that particular product component then decides on selecting the automation tools compatible for that component. The automation specialists are involved in designing Regression tests for the verification of the product components. This site is also involved in designing the automated integration test intended to test the customer workflows. The test automation process map for Site D is shown in Figure 5 below.

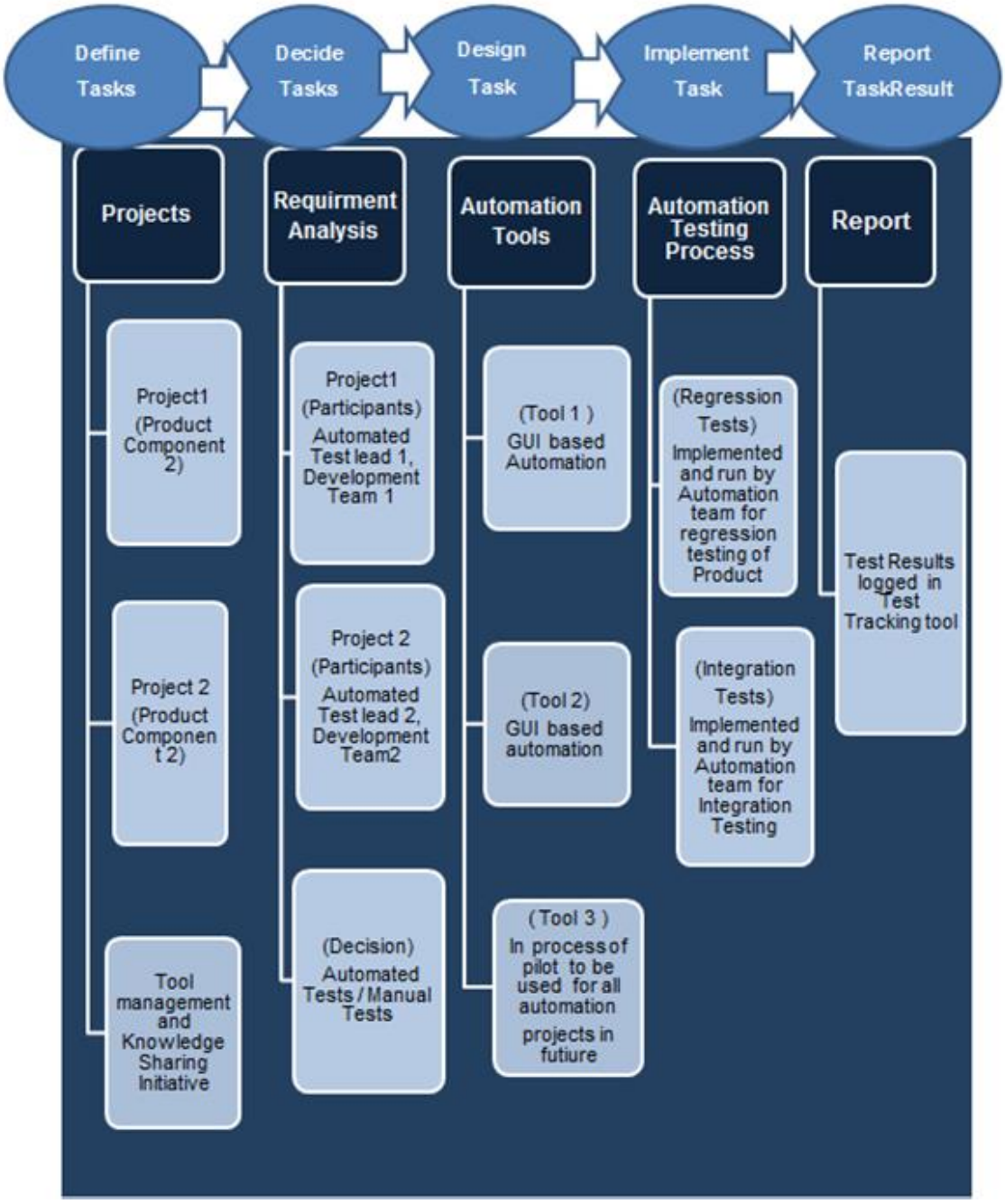

Figure 5: Test Automation Process Map-Site D

As illustrated in Figure 5 above, this automation site is involved in automation projects for the product component manufactured by the same development center using multiple GUI based automation tools.

Key Findings and Analysis-Site D

This automation site invests in GUI based test automation for multiple product components at the same time. This site is involved in mostly designing GUI based functional

verification and they do not design any automated verification tests to test the product code or unit testing of product component.

Close Collaboration between the development and test automation unit exists at a functional level but the automation resources do not have access to the source code of the product component. The automation team is totally dependent on the development team or the failed automation test results for any kind of changes at the product end.

Each automation lead dealing with the test automation of that particular product component has in depth domain knowledge of that product component as well as excellent skill sets related to automation tools and technology.

This automation unit has some kind of collaboration with the other automation sites as the automation department of this site is responsible for managing tool licenses and version upgrades for automation tools. This site is responsible for providing service related to license upgrades or tool related problems to other sites.

This site has initiated a knowledge sharing forum for the automation resources of different sites of the case company located at different geographical locations. This knowledge sharing forum was intended to post the queries, problems related to test automation and other important updates related to automation tool and license. Lately this forum is not much in use after the product owner of this forum left the case company.

A selected set of automation resources in this site is involved in doing a pilot of automation tools and process in order to standardize the automation process for the unit. This team is also in the process of interaction with the other sites to evaluate the best practice used at the development sites.

All the tools and technology used for the planning, designing and implementing the tests are well maintained and validated for the intended use. Hence, the automated tools satisfy the criteria of quality related standards and up to date for quality related audits.

A summary of the strengths and challenges of the automation department (Site D) is shown in Table 7 below.

Table 7. Strengths and Challenges-Site D

Key Issue	Strengths	Challenges
Knowledge Sharing	• Initiative of knowledge sharing forum to collaborate with other test automation sites for exchange of knowledge and best practice • Pilot to evaluate best practice at other automation sites in order to adapt a stable single automation framework to suit the need of automation projects	
Product Domain Knowledge	• Strong knowledge base for the product line with special skilled resources	• No access to product code base which causes gap to keep pace with changes at product side.
Tool Maintainaibility	• Up to date tools and technology for quality related audits • Excellent skill sets related to automation tools ,technology and license handling • No dependency for automation tools or license on other site	• Redundant audit related documents due to several tools used in projects
Test Coverage	• Good Knowledge Base in GUI based Automation	• Lack of knowledge base in code based verification tests • Lack of automated unit tests
Test Framework and Test Architecture		• Lack of formal documentation for test automation architecture

As seen from Table 7 above, this test automation unit of the case company has strong product domain knowledge as well as skill sets for knowledge sharing between the teams but lacks in terms of API based test coverage.

3.5 Test Automation Department -Site E

The automation department of this unit is involved in designing GUI based automation tests. This automation unit designs GUI based automated tests for the verification of the product component manufactured by this sites. The automation lead in collaboration with the development team as well as manual testers decides on the functional requirements to be covered by automated tests. More than one automation tool is used to design the automation tests for different parts of that product component. The test automation lead makes the decision about the testing tool to be used for the automation. The automated tests are designed for formal regression testing of product verification. The test automation process map for Site E is shown in Figure 6 below.

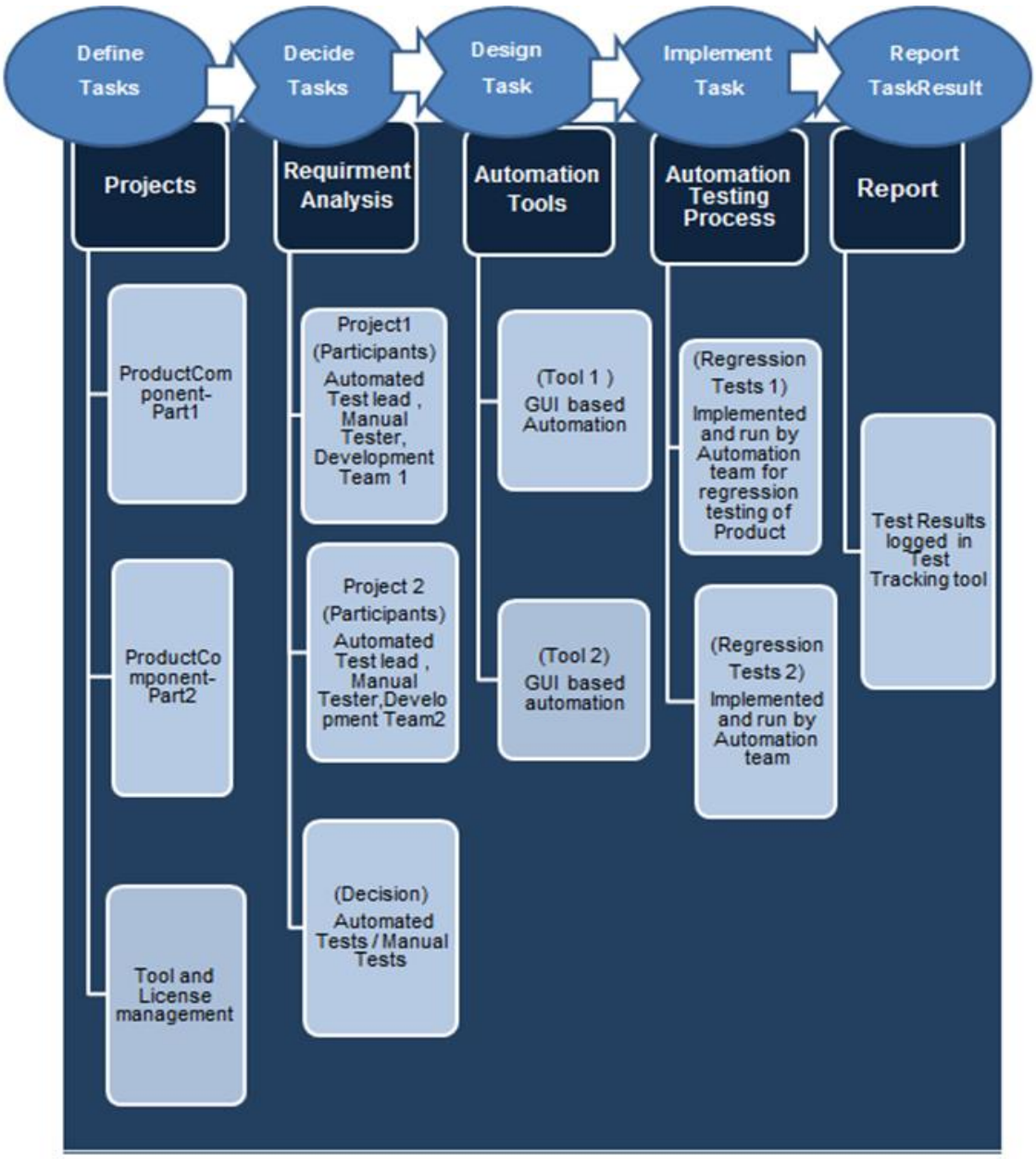

Figure 6: Test Automation Process Map-Site E

As illustrated in Figure 6 above, this automation site is involved in automation projects for the product component manufactured by the same development center using multiple GUI based automation tools.

Key Findings and Analysis-Site E

This development site has an automation department with self-managed automation testing tools and processes suiting the need of this development center. The product component manufactured by this development center has very little dependency on the product components manufactured by the other sites. Hence, the automation unit of this site follows a closed approach when it comes to collaboration and communication with the other automation sites.
The test automation site is very particular about the automation tools and existing testing practice used by this site. This site has no dependency for automation tools or license on the other automation sites as the site manages its own testing tool and license server.Thus, this site is not very open and keen on knowledge sharing collaboration with the other automation sites.

This automation department is involved in designing only GUI based automation tests for functional regression testing. This site does not design automated tests for unit testing or tests to verify the product codebase. Close Collaboration between the development and test automation unit exists for this development center. The automation team is well updated about the upcoming changes in the product line. This process helps in advance planning for the changes in existing automated tests as well as designing new tests.

The decision for selecting the requirements for the automated regression tests is made in collaboration with the development team. This process makes a clear division of tasks between manual testers, automated tester and developer which removes the probability of overlapping and redundant tasks.

All the tools and technology used for the planning, designing and implementing the tests are well maintained and validated for the intended use. Hence, the automated tools satisfy the criteria of quality related standards and up to date for quality related audits.

A summary of the strengths and challenges of the automation department (Site E) is shown in Table 8 below.

Table 8. Strengths and Challenges-Site E

Key Issue	Strengths	Challenges
Knowledge Sharing	• Cross functional teams including automation specialist , manual testers and development team for internal knowledge sharing	• Lack of collaboration in test automation effort with other test automation sites
Product Domain Knowledge	• Strong knowledge base for the product line with special skilled resources • Close collaboration with development team which helps to track and get updated about upcoming changes in product line	
Tool Maintainaibility	• Up to date tools and technology for quality related audits • No dependency for automation tools or license on other site	• Redundant audit related documents due to several tools used in projects
Test Coverage	• Good Knowledge Base in GUI based Automation	• Lack of knowledge base in code based verification tests • Lack of automated unit tests
Test Framework and Test Architecture		• Lack of formal documentation for test automation architecture

As seen from table 8 above, this test automation unit of the case company has strong product domain knowledge as well as automation skill sets but lacks in terms of API based test coverage and collaboration with other automation sites.

3.6 Summary of Current State Analysis

The current state analysis of the test automation units of the case company was carried out by analysing the current state data of each automation unit individually. The analysis of the current state data reveals that many of the current challenges faced by the automation units can be addressed by internal knowledge sharing of best practices with each other. Table 9 below shows mapping of challenges faced by automation sites with best practice of another automation site.

Table 9. Challenges Vs Best Practice data mapping

Challenges	Impacted Sites	Best Practice	Contributor Sites
Knowledge Sharing • Lack of collaboration in test automation effort with other test automation sites	Site A, Site B, Site C, Site E	• Initiative of knowledge sharing forum to collaborate with other test automation sites for exchange of knowledge and best practice	Site D
Product Domain Knowledge • Lack of domain knowledge in core product components makes integration testing task challenging	Site A, Site B,	• Cross functional teams including automation specialist, manual testers and development team for knowledge sharing. • Strong knowledge base for the product line with special skilled automation resources	Site C, Site E Site D, Site C
• No access to product code base which causes gap to keep pace with changes at product side.	Site A, Site B, Site D	• Close collaboration with development team which helps to track and get updated about upcoming changes in product line	Site C

Tool Maintainability • Redundant audit related documents due to several tools used in projects • Too much tool options create confusion at times. It results in selecting wrong tool from repository which at times discovered very late during the project	Site B, Site C	• Single stable automation tool which is easy to maintain and requires less documentation for audit purpose • Pilot to evaluate best practice at other automation sites in order to adapt a stable single automation framework to suit the need of automation projects	Site A Site D
Test Coverage • Lack of knowledge base in code based verification tests • Lack of automated unit tests • Lack of GUI based automation	Site D, Site A, Site B Site D, Site A, Site B Site C	• API based automated test suits which covers unit tests and code based verification tests • Excellent Knowledge base for GUI based automation and compatible automation tools several product lines	Site C Site C Site D, Site A, Site B
Test Framework and Test Architecture • No fixed strategy or guideline to design tests • Outdated and complex Test Automation Framework which is difficult to maintain.	Site C	• Automation department uses same technology to design tests as product development team. Hence, test scripts are easy to maintain as well as stable and sustainable for long run • Data driven automated tests which are easy to maintain and well structured	Site A Site B, Site D

As shown in Table 9 above, internal knowledge sharing of best practice with each other between the automation units can overcome many of the challenges faced by the automation sites.

Based on the analysis of the five sites it is clear that each automation site implements test automation projects in a very unique way. Moreover, each site is having a distinct set of specialized knowledge related to automation tool, technology, process, framework and architecture for test automation projects. Hence, each site is having enor-

mous potential and knowledge which can be utilized by the other sites to address the knowledge need faced by another site.

4 Best Practice for Knowledge Management

The outcome of the current state analysis of this study suggests that the automation units face challenges in terms of knowledge sharing, tool maintainability, product domain knowledge, test coverage and issues related to test framework and architecture. A detailed examination of the automation sites' data reveal that issues faced by the automation units are linked with lack of knowledge sharing activities between the automation sites. The automation sites could help each other in sorting out these challenges by sharing existing knowledge base with each other.

This section of the study hence discusses existing literature and best practice available for organizational knowledge creation, knowledge management and knowledge sharing process which contributes towards building a consistent and reliable knowledge management framework for sharing knowledge between the embedded units in a geographically scattered organization.

4.1 Knowledge Creation in Organizational Context

In an organizational context, knowledge creation is a two-step transformation process from data to knowledge. Data can be defined as a structured record of facts, events or transactions happening in an organization on a day to day to day basis but data does not reveal justification or interpretation of action by itself (Davenport and Prusak 2000:2). Data is transformed into information by adding context and meaning to the recorded data. Data is then transformed into information by contextualizing, categorizing, calculating, correcting and condensing the collected data (Davenport and Prusak 2000: 3). Finally, humans perform knowledge creation activity on the information in order to transform it into Knowledge (Nonaka 1994:15). Adding attributes like comparison, consequences, connection and conversation of several human beings on that particular information transform the information into knowledge (Davenport and Prusak 2000: 5). Figure 7 below shows the two-step workflow for the knowledge creation process from data to information.

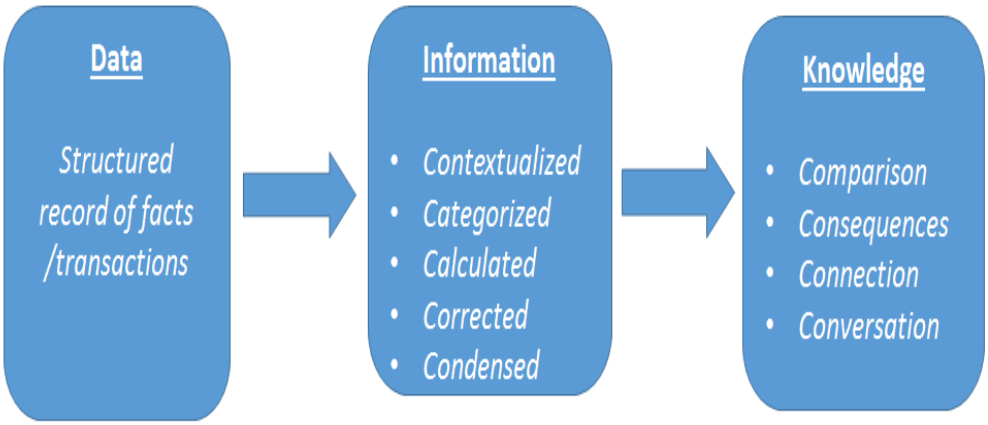

Figure 7. Transformation of Data to Knowledge diagram (Based on Davenport and Prusak 2000: 4-15)

As illustrated in Figure 7 above, when data is transformed into knowledge, it becomes more valuable and meaningful. Hence, information is the commodity capable of yielding knowledge whereas knowledge can be defined as information based on true belief of knowledge creator which can be justified by truthfulness (Dretske 1981:44). In other words knowledge can simply be defined as justified true belief (Nonaka 1994:14). In other words, the events or facts of an organization when transformed from data to knowledge, it becomes closer to human action which can be reused in a similar situation by a knowledge creator or other organizational human resources.

The knowledge creation process in an organization is driven by individual human resources but there are two kinds of knowledge through which individual knowledge can be created or accumulated. One is *tacit* knowledge which an individual learns through his or her own hands on experience during the learning process in the organization which is highly influenced by the high quality of experience which the user goes through in their day to day work. Hence tacit knowledge is always impacted by action, experience and commitment in a particular surrounding and context (Nonaka 1994:16). The second kind is *explicit* knowledge which is created or accumulated through organizational process like trainings, readings or other explicit knowledge creation methodology of the organization (Nonaka 1994:16). As Davenport and Prusak state:

> Knowledge is a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers. In organizations, it often becomes embedded not only in documents or repositories but also in organizational routines, processes, practices, and norms (Davenport and Prusak, 2000: 4).

Tacit knowledge and explicit knowledge together interact with each other to transform existing knowledge in to a new knowledge. Nonaka (1994:16) describes a spiral model of knowledge creation through four modes of interaction between tacit knowledge and explicit knowledge for conversion from existing knowledge to new knowledge. Figure 8 below shows conversation modes between explicit knowledge and tacit knowledge for knowledge creation.

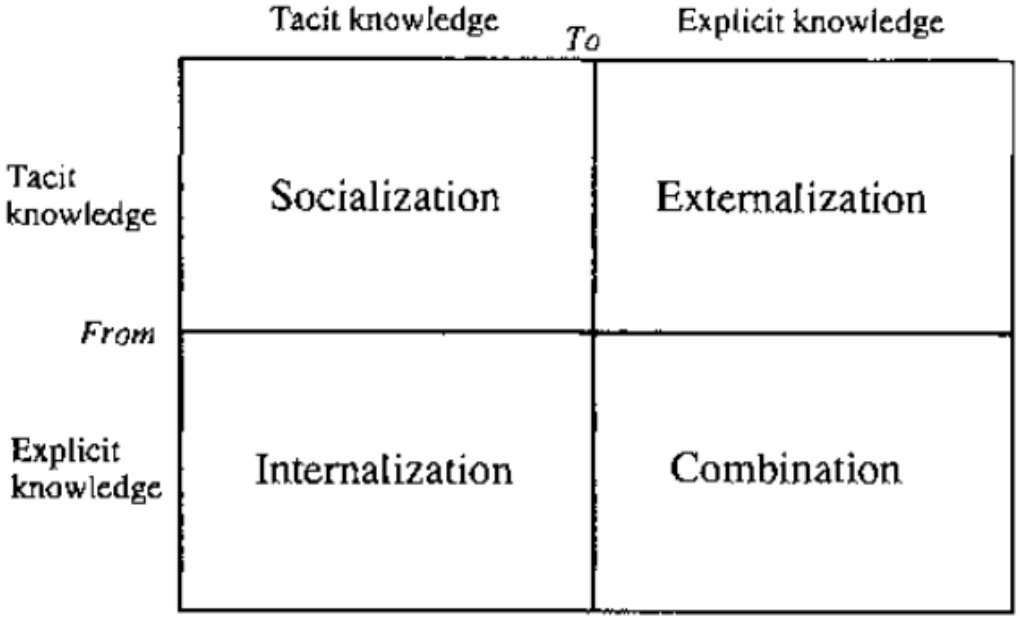

Figure 8. Modes of Knowledge Creation (Nonaka 1994:16)

As illustrated in Figure 8 above, various ways of conversation between tacit and explicit knowledge contributes towards new knowledge creation. 1) Socialization between individuals occurs when tacit knowledge is shared with the tacit knowledge of other people. 2) Combination of various kinds of explicit knowledge in the organization using social mechanism like meetings, phone or forums creates new knowledge. 3) Explicit to Tacit knowledge conversation also creates new knowledge through traditional learning process in the organization called Internalization. 4) Externalization between different

units, departments or even different organizations occurs through learning and interaction between them which contributes for new knowledge creation.

Hence, the knowledge base of the organization continuously increases and becomes larger in scale when knowledge is shared within the team, internal departments, other development units and even external contributors like customers. Figure 9 below is the spiral mode of knowledge creation in the organization:

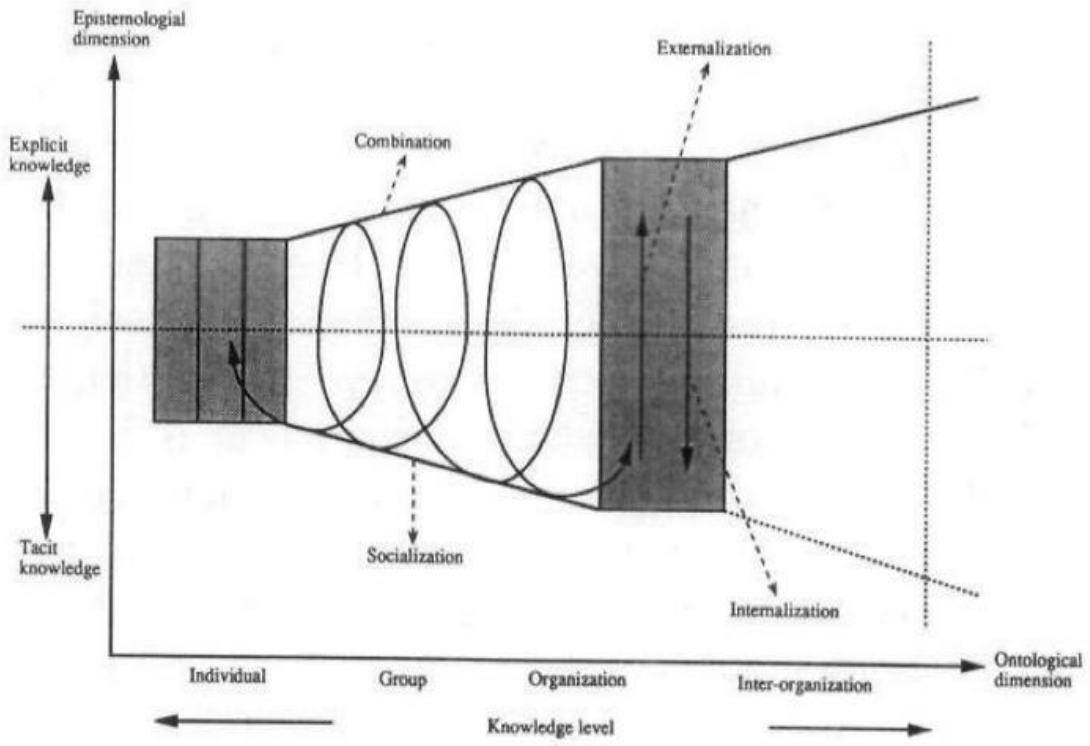

Figure 9. Spiral Mode of Knowledge Creation (Nonaka 1994:20)

As illustrated in Figure 9 above, organizational knowledge is created in a spiral process where the creation of knowledge takes place through continuous cycle of interaction between various kinds of existing knowledge. Since knowledge is continuously getting created in the organization, it is also important to apply the existing knowledge base in the organization in order to get benefitted by reusing the created knowledge. Hence, organizations need to have a system in place to manage and reutilize the created knowledge to achieve organizational goals.

4.2 Knowledge Management

Organizations often face problems to identify, access and use an existing knowledge base distributed across the units. This problem of converging and utilizing existing

knowledge can be resolved by a strong Knowledge Management (KM) system (Cummings 2003).

For scattered organizations dealing with information technology (IT), there is always a vast existing knowledge base in various areas which is important to achieve business goals. A knowledge management system in the IT industry is a system to store and retrieve knowledge, collaborate with knowledge resources to capture and utilize knowledge in order to enhance the knowledge base for organizational need (Bali et al.2009). Knowledge management is an essential process to address many existing business needs as well as the knowledge need of the organization (Rus and Lindvall 2002:27-28).They described the need of KM to resolve business issues mentioned below:

First of all, Software Industry continuously faces the pressure to catch up with emerging tools and technology in the market to fulfil their business needs. KM is needed to quickly acquire and master the upcoming tools and technology. Hence, the KM system empowers the organization to enhance the needed knowledge base related to new tools and technology.

Secondly, multinational organizations continuously expand their business in different parts of the globe by merger, acquisition, offshoring or opening a new business unit in a new market segment. Such international business strategy often give rise to challenges related to product domain knowledge as product domain knowledge is geographically scattered across the units. A centralized Knowledge Management system acts as an important tool to converge the scattered domain knowledge to be accessed and utilized by all other business units.

Thirdly, Business units often face technical issues which can be resolved by experts and existing knowledge base with another unit of the organization. KM can be used to resolve these challenges quickly and efficiently by capturing existing knowledge and identifying expert resources who can be contacted for a quick fix of the issues.

Finally, KM also helps in collaborating Knowledge sharing between units for organizations having multiple embedded units working towards achieving common goal. KM is used to collaborate knowledge sharing between units in order to decrease time, cost and increase the quality of deliverables for each site.

Thus, Knowledge management (KM) system on the one hand help organizations in addressing business needs like taking prompt and cost effective decisions whereas on other hand it helps to sort out issues of knowledge needs related to technology, tool, domain knowledge and best practices. Hence knowledge management is an essential process to manage knowledge-related activities in the organization starting from creating knowledge, storing created knowledge, transferring knowledge, and re-using knowledge (Bhatt, 2000). Figure 10 below explains the four-stage knowledge management activity starting from creating the knowledge to applying the created knowledge.

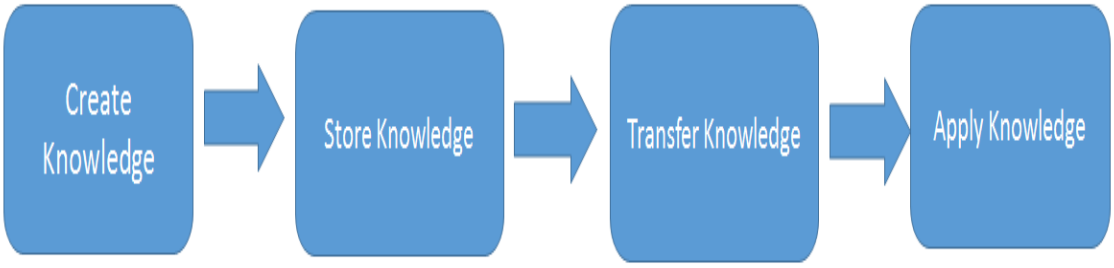

Figure 10. Four Stages of Knowledge Evolution: Based on (Alavi and Leidner 2001)

As illustrated in Figure 10 above, Alavi and Leidner suggest that knowledge management is a continuous process which evolves from creating knowledge to storing, transferring and reutilizing created knowledge.

Section 4.1 of this study gave an overview of methodologies for knowledge creation in an organization. Once the knowledge is created, knowledge need to be stored in organized manner in order to retrieve the created knowledge for re-use. Organizational knowledge storage includes storage of knowledge related to tool, technology, domain knowledge or best practices (Lindsey, 2003). These knowledge storages are referred as experience database or knowledge repository in organizational context (Rus and Lindvall 2002:30). Global Information technology (IT) organization uses tools like subversion, team foundation servers or SharePoint to store the available knowledge which can be retrieved globally across the departments and units so that created knowledge base can be used by others to achieve organizational goal (Bierly et al. 2000).

Sharing knowledge is an important stage of knowledge management for transferring created and stored knowledge in an organization. Cummins suggests several mechanisms for knowledge transfer across the scattered units of a global organization (Cummings 2003:102). Figure 11 below is the several mechanism of knowledge transfer in the organization.

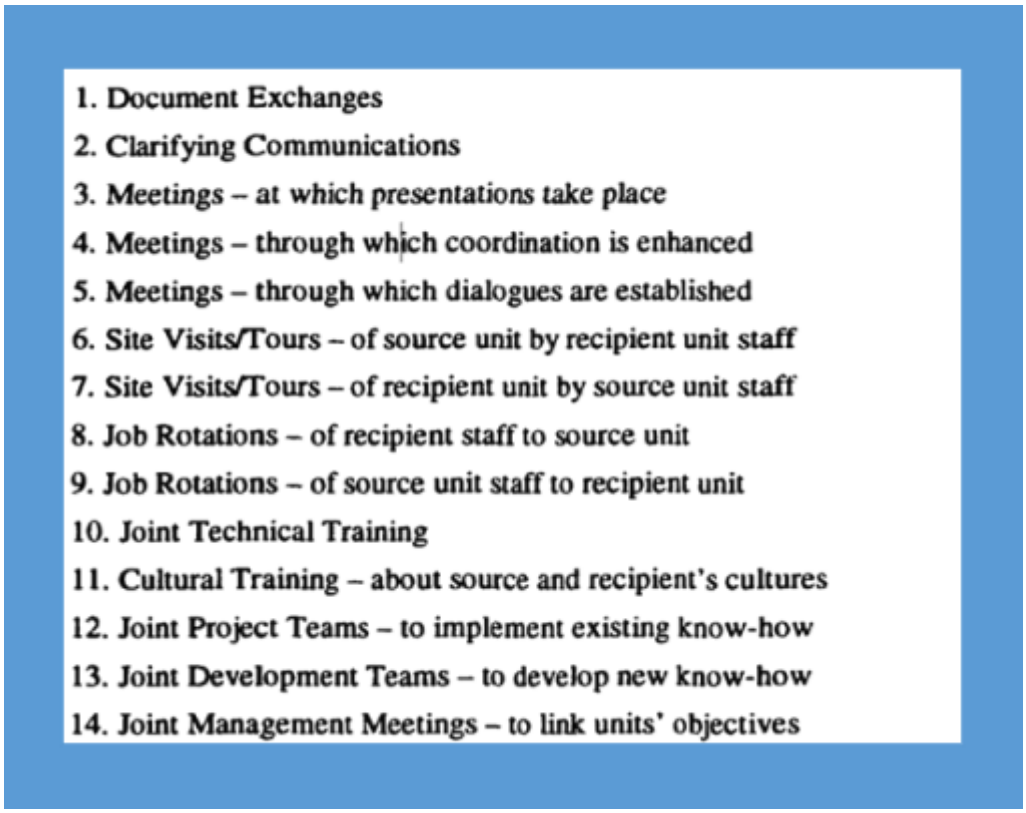

Figure 11. Knowledge Transfer Mechanisms (Cummings 2003:102)

As illustrated in Figure 11 above, knowledge sharing processes between units in an organization can be implemented by joint efforts like site visits, trainings, meetings and various means of communication.

After the knowledge transfer is done, the acquired knowledge needs to be utilized and implemented to achieve individual and organizational goal (Bierly et al. 2000: 602). In order to utilize the transferred knowledge, individual needs to learn the acquired knowledge before they apply the knowledge to perform task using that knowledge. Hence learning is an important and integrated part of knowledge management process where individual knowledge level is elevated by sharing and learning the new knowledge to perform organizational tasks (Rus and Lindvall 2002:29).

Thus knowledge management is an essential organizational process of synthesizing individual knowledge to structured organizational knowledge base. Knowledge base is then used to connect people with knowledge to serve as a tool to contribute towards achieving organizational goals.

4.3 Key Influencing Factors for Successful Knowledge Management

Efficient Knowledge management strategy is important for organizational growth by converging scattered knowledge base across the departments and units. For successful implementation of knowledge management system in the organization, environmental factors surrounding knowledge sharing process needs to be analysed and addressed carefully (Lindsey 2003:12). Environmental factors impacting governance of Knowledge management system could be summarized in three major categories like organizational factors, cultural factors or technical factors (Tabrizi and Morgan 2014:55). These environmental factors act as supporting and motivating tools for implementing knowledge sharing process. Figure 12 below explains Governance mechanisms of knowledge sharing in the organization based on Tabrizi and Morgan.

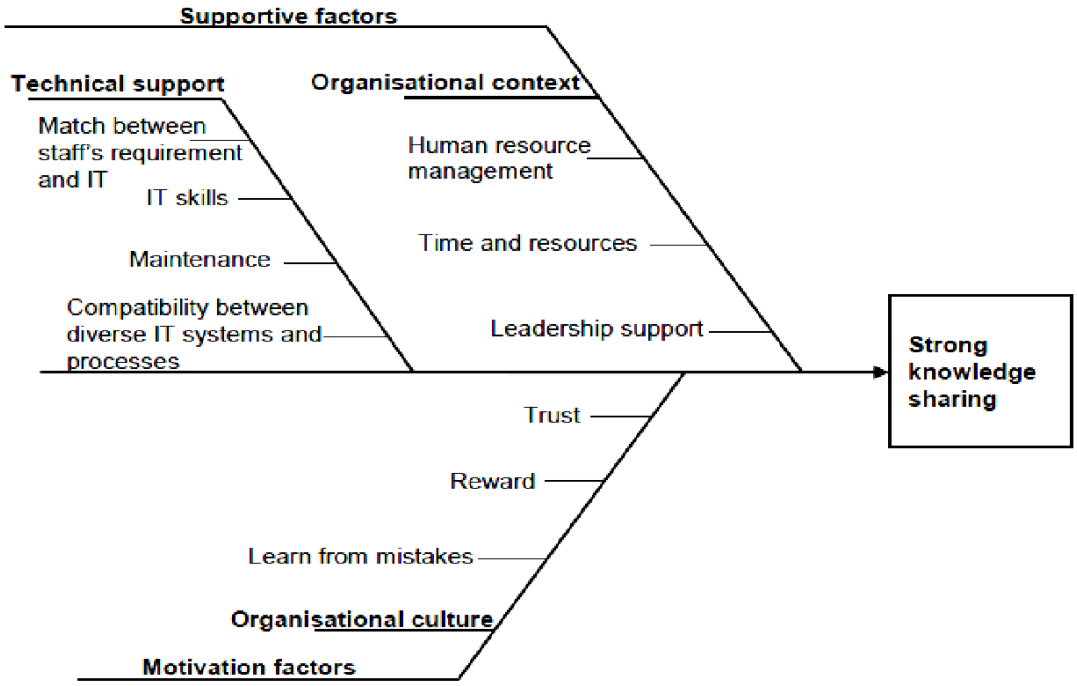

Figure 12. Governance mechanisms of knowledge sharing (Tabrizi and Morgan 2014:56)

As illustrated in Figure 12 above, environmental factors play an important role towards successful implementation of strong knowledge sharing process. These environmental

factors can be grouped together in three major categories consists of Technical factors, Organizational factor and Cultural factor. Technical factor concerns to tools, technology needed to support knowledge sharing system .Moreover organization factors related to leadership commitment, resource allocation and HR policies also acts as supportive factor to implement knowledge sharing activities in the organization. Finally, cultural factors like rewards to contributors trust in knowledge sharing resources and freedom to learn at work place act as a motivational factor for promoting strong knowledge sharing in the organization. Bhatt (2002) suggests that an organization can emphasize implicit work practices and methodologies during day to day routine tasks in order to promote knowledge sharing activity in the organization. Figure 13 below shows the role of the organization in promoting knowledge sharing in the organization.

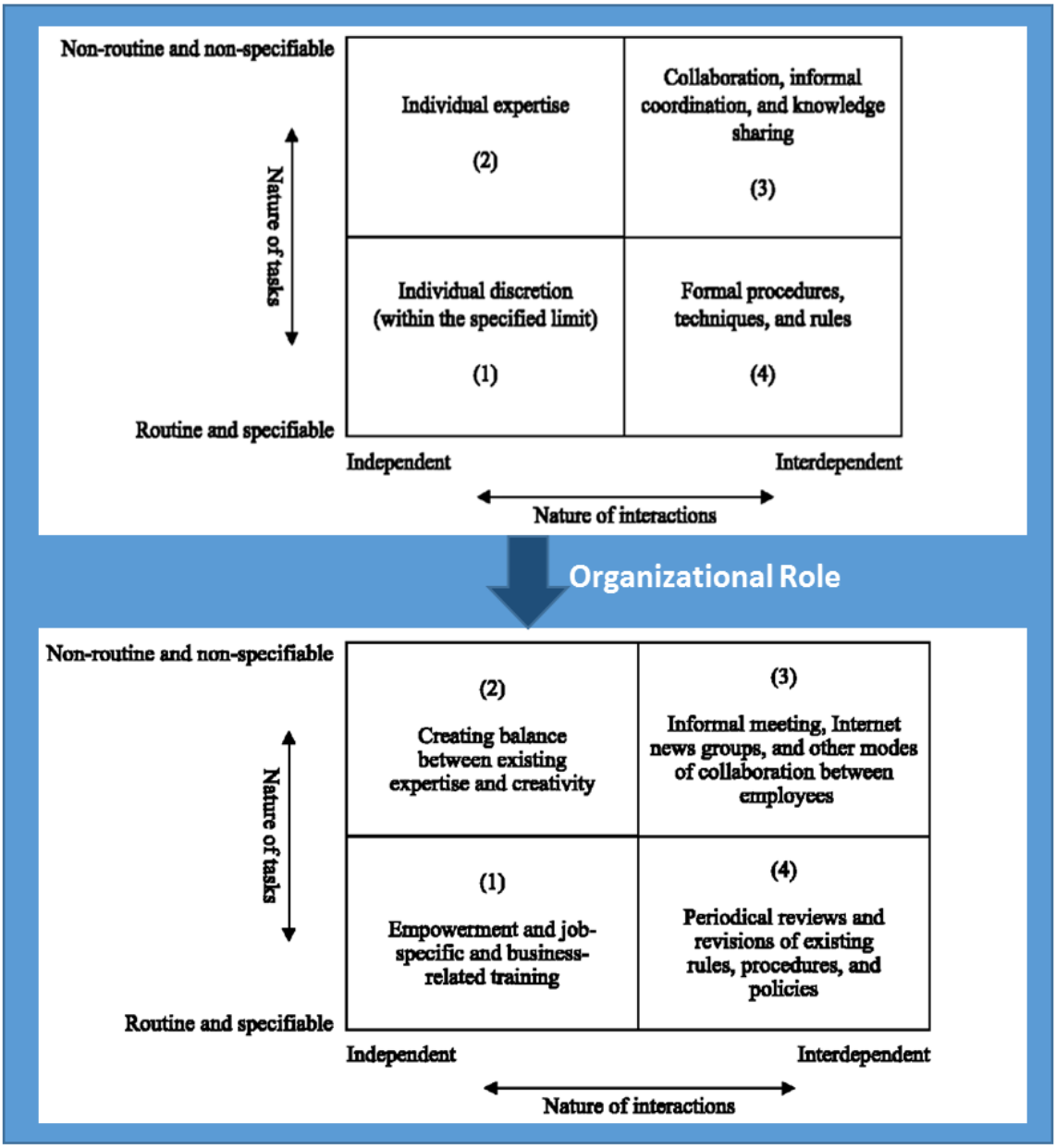

Figure 13. Organizational role to promote knowledge sharing (Based on Bhatt 2002)

Figure 13 above illustrates the role of organizational culture to promote knowledge sharing activity in routine and non-routine tasks of employees. Bhatt suggests that measures like training, review, freedom for creativity and informal group meetings in the organization promote knowledge sharing activity in the day to day work of the employees.

4.4 Models for Knowledge Management Framework

While Knowledge management is treated as a standalone framework or strategy by most of the scholars, some of the scholars and researchers described knowledge management as a complete end to end process for managing knowledge related activity in the organization to achieve organizational need and goal.

Dotsika and Patrick (2013) describe a six-stage knowledge management model for successful implementation of end to end knowledge related activities. This knowledge management model is a cyclic model consists of six phases. Figure 14 below tasks and action points of each phase of the knowledge management model described by Dotsika and Patrick (2013).

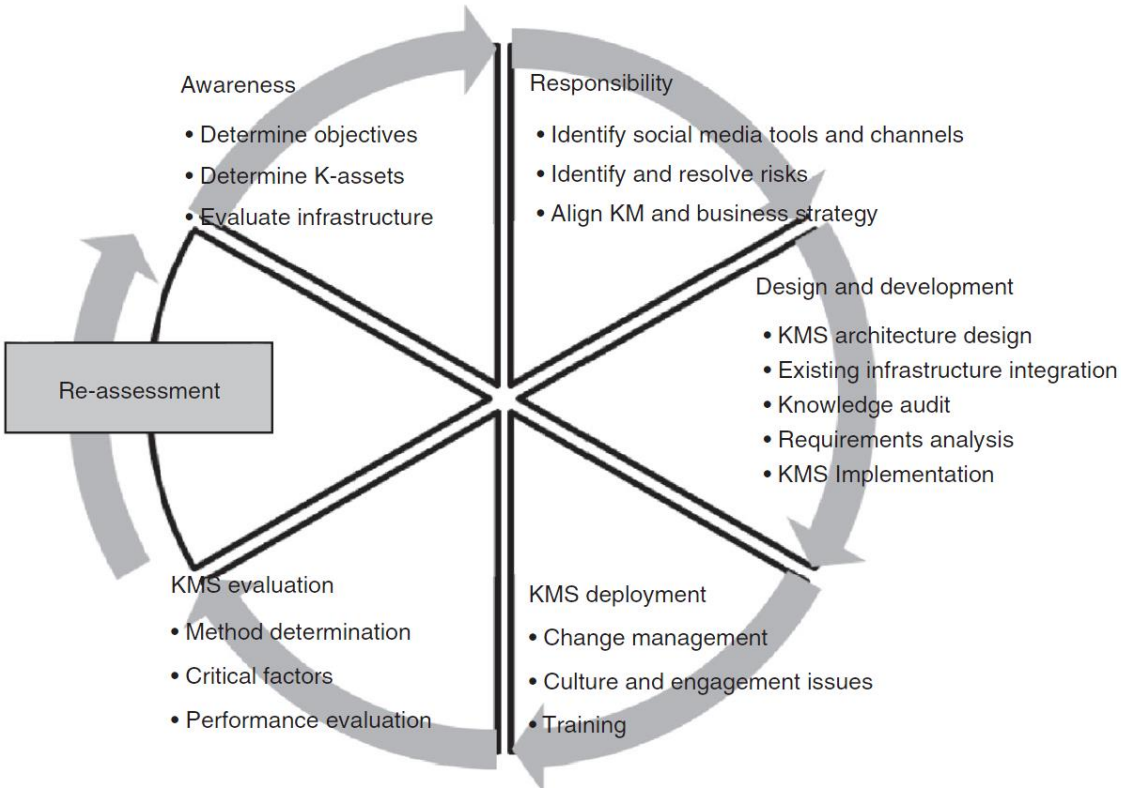

Figure 14. Knowledge Management Model (Dotsika and Patrick: 2013)

As illustrated in Figure 14 above, Dotsika and Patrick suggest a knowledge management model which starts with an initial analysis of the objective, followed by planning, implementation, evaluation and reassessment of the entire knowledge management process to fulfil the organizational goal. At the beginning of KM cycle, a detailed analysis of objective as well as assessment of Infrastructure and needed assets for achieving the objective is also done. Once the objective is set for KM, responsibilities to handle the technical as well as organizational factor linked with implementation of KM are assigned to the concerned resources. The allocated resources then design and implement KM activity in the organization. Once the KM process is in practice in the organization evaluation of performance is done to measure the success of the KM system to achieve the set objective for the KM cycle. Finally, a reassessment is done to measure and record learnings from the current KM cycle which contributes towards better planning of the next KM cycle.

Tabrizi and Morgan (2014) on the other hand suggest a four-stage knowledge sharing model for managing end to end knowledge related activity in the organization. Knowledge Management process in the organization is a continuous process which consists of Initiation, Requirements, Implementation and Follow up stage. Figure 15 below explains tasks and action points of each phase of the knowledge management model described by Tabrizi and Morgan (2014).

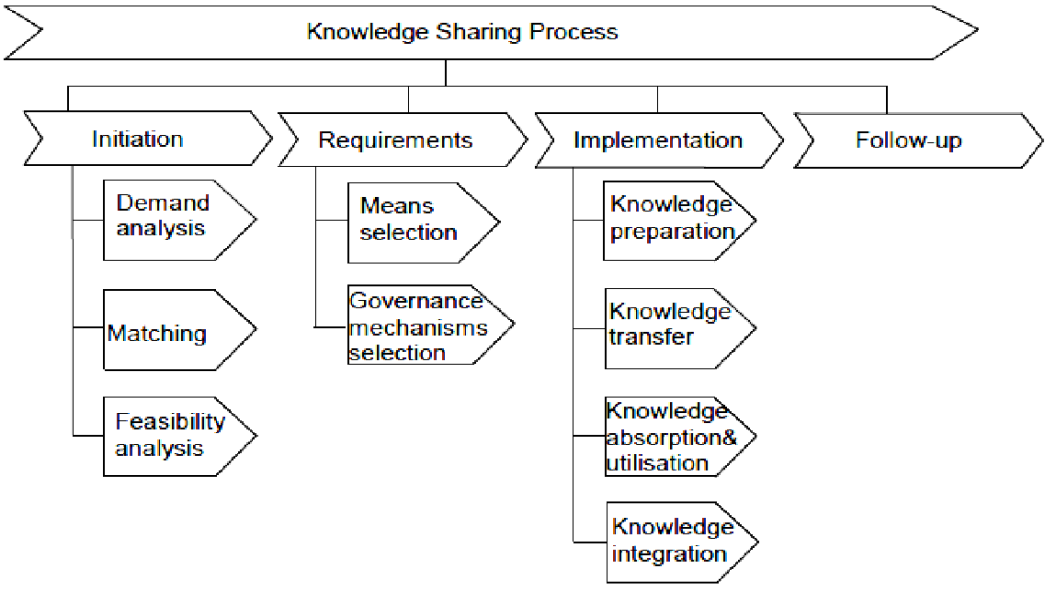

Figure 15. Knowledge Sharing Model (Tabrizi and Morgan: 2014: 53)

Figure 15 shows how Tabrizi and Morgan (2014) grouped entire KM activities in four major stages consisting of Initiation, Requirements, Implementation and Evaluation.

During *Initiation* phase, detailed analysis of Objective for the knowledge management activity is done. Moreover detailed assessment of Infrastructure as well needed assets for the implementation of knowledge management activity is also done in this phase. Hence, this stage is important for planning the next stages as the output data of this phase gives an early insight of associated strengths and challenges associated with entire KM system.

In the *Requirement* phase a detailed analysis of Environmental factors is conducted. This stage gives information of the necessary actions needed prior to actual KM implementation. Tabrizi and Morgan suggest that people work under different organizational and local culture. Hence, they need to be motivated and encouraged through trainings, formal change management process and various communication means for participating in knowledge management activities.

Implementation stage starts with preparation of knowledge by human resources working for the organization. Once the knowledge is prepared, it is transferred to other departments and units for re-using the prepared knowledge. Transferred knowledge is then utilized by the other units and teams to achieve organizational goal. Once humans utilize the prepared knowledge, it gets integrated with explicit and tacit knowledge of the resource performing the action. This Integration of existing knowledge with transferred knowledge creates new organizational knowledge.

The final stage of this KM model is the *Evaluation* phase which consists of an evaluation of the earlier phases of the process as well as to retrospect the entire KMP. This phase is important because the output data of this phase is important for the Initiation phase as this phase helps to take corrective measures needed to be taken during the initiation phase of the next KMP cycle.

Thus, Knowledge Management (KM) is an end to end cyclic process to facilitate successful implementation of knowledge management activity in the organization starting from planning, implementation and evaluation of KM activity.

4.5 Conceptual Framework for Knowledge Management

The literature discussed above suggests a need for a knowledge management framework for managing knowledge sharing activity between units to achieve the research objective of this thesis.

Figure 16 below condenses the key issues into a conceptual framework to manage knowledge related activities between the sites of the case organization to fulfil the knowledge need of geographically scattered sites.

Conceptual Framework for Knowledge Management

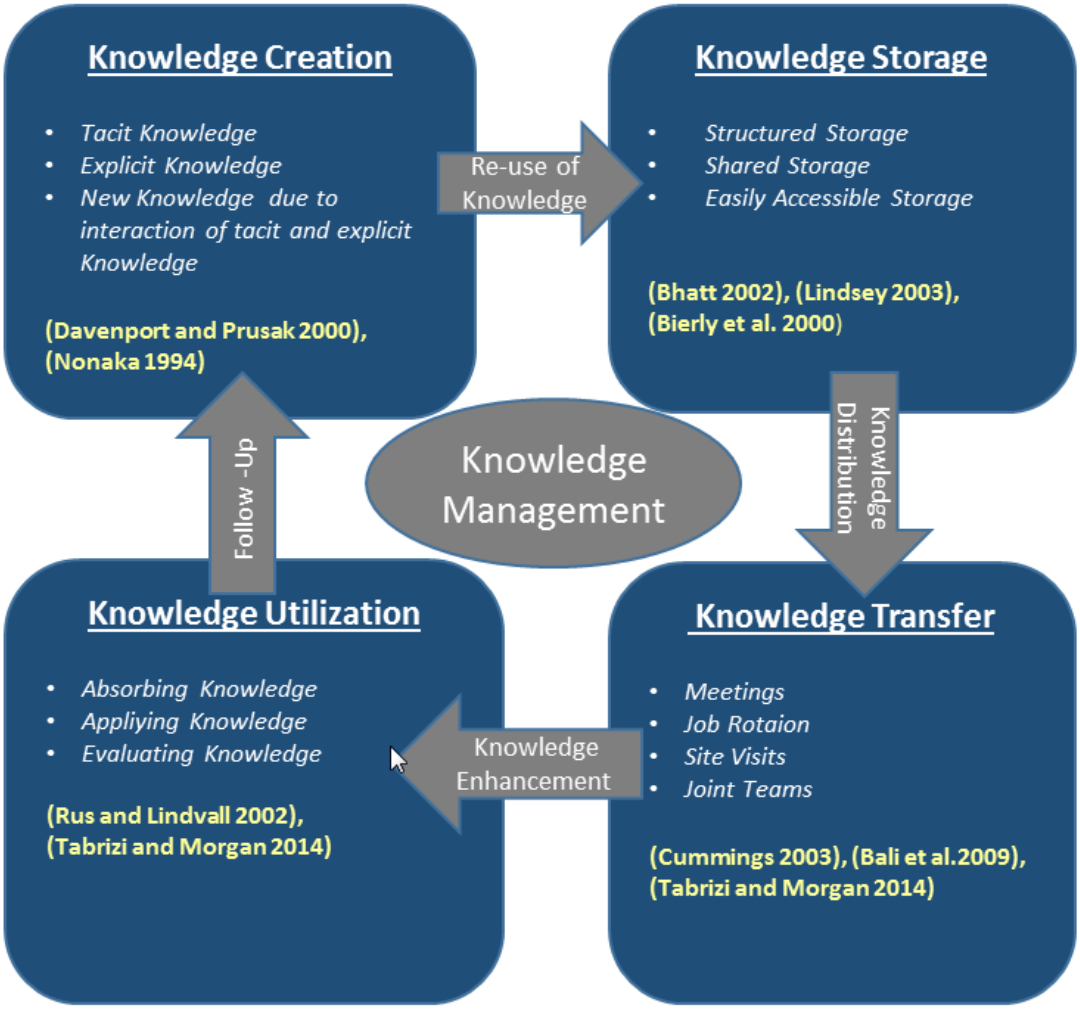

Figure 16. Knowledge Management Framework

As shown in Figure 16, knowledge management (KM) framework is a four-stage cycli-

cal process which consists of knowledge creation, knowledge storage, knowledge transfer and knowledge evaluation.

The first stage is Knowledge Creation phase where individual human resources contribute with their tacit and explicit knowledge towards creating knowledge base for the organization. Organizational knowledge in this phase continuously increases in volume by integrating new knowledge to existing knowledge.

The second stage of KM framework emphasizes on creating knowledge repository for centralize storage of created knowledge. Centralized, structured and shared storage of knowledge helps organization to easily retrieve and re-use existing knowledge for organizational need.

The third stage of KM framework consists for knowledge transfer mechanism in order to share and transfer stored knowledge to other departments and business units by various knowledge transfer techniques. Even if the knowledge base is stored centrally, exchange of information between units is needed about existing knowledge so that other units know and utilize existing knowledge.

The fourth stage of knowledge management framework is knowledge utilization phase which is final stage KM framework. This stage promotes utilization of the transferred knowledge to achieve individual and organizational goal. This stage creates new knowledge due to integration of transferred knowledge with existing tacit and explicit knowledge of human resource who utilizes the transferred knowledge. This four-stage KM framework thus helps to evolve new knowledge which is then integrated with the existing knowledge base for continuous growth of organizational knowledge.

Thus, the proposed knowledge management system can cater to the need of a geographically scattered organization to capitalize its distributed knowledge base in order to share and re-utilize the existing knowledge capital to fulfil knowledge need of each site.

5 Building Draft Proposal for Knowledge Management System

This section takes to the data collection 2 of the study which was organized with the stakeholders of the test automation sites. In this section, the outcome of the current state analysis and the conceptual framework are merged towards building the proposal for implementing the KM activities for the automation sites in the case company.

5.1 Development ideas for the Proposal based on Stakeholder Discussions

The current state analysis results of this study revealed several challenges faced by the individual automation sites due to a gap in knowledge sharing activities between the sites. The stakeholders of test automation sites as described in Section 2 Table 2 were further involved to get the ideas and suggestions about how to improve the existing knowledge sharing system of the case company. The stakeholder discussions are now reported in three major categories of improvement needs which are linked to the storage of test automation knowledge, utilization of existing test automation knowledge and improvement of communication between the sites.

Improvement needs related to storage of Test Automation Knowledge:

Based on a discussion with the stakeholders of the automation sites, it was evident that "Team Foundation Server" (TFS) is an acceptable solution for a knowledge storage system to all sites of the case company but improvements were needed to make the repository usable and accessible to all sites. A few of the suggestions which came out of the discussions were as follows:

Firstly, it was agreed that automation units still need to capitalize all existing knowledge to the *single repository system* as there are several other storage systems like subversion and SharePoint in use for the similar purpose. The automation units need to transfer all existing technical knowledge from other repositories to Team Foundation Server (TFS) in order to have a single centralized knowledge repository.

Secondly, it was reported that each site uses a different structure pattern to save the technical data in TFS. A huge amount of technical data and diversity in storage structure makes it complex and difficult to search for the needed data by the other sites. Hence *a similar and relevant structure pattern for repository for all sites* is suggested which could be useful to make the available data easily accessible by the other sites.

Finally, it was reported that the automation data of each site is right protected in a knowledge repository system which makes it inaccessible to the other sites in the hour of need. Getting access rights on the needed data sometimes takes days as it is hard to find resource at other site who can give access to the needed data. Hence, advance planning and *granting of access right on test automation data* can make the existing automation knowledge quickly and easily accessible to all sites.

Improvement needs related to Utilization of existing Test Automation Knowledge:

The stakeholder discussions revealed that the case company is having a resource pool of extremely talented test automation experts. Specialized skills related to framework designing, product domain knowledge and expertise related to automation tools and technology is distributed across the automation sites. It was agreed in the discussion that there is a *need of converging these scattered test automation skills and knowledge* to be utilized by all units. A few of the suggestions which came out of the discussions were as follows:

For framework related challenges, it was discussed that a uniform test framework and architecture which can fulfil the acceptance criteria of all sites could be a long term solution for resolving architecture related challenges faced by the automation sites. At the same time it was acknowledged by site representatives that it is difficult to get a common solution for all sites due to the unique and complex nature of product components tested by the automation sites.

For tools and technology related issues, it was suggested to establish a cross functional team of automation resources from all sites. This team can look into the possibilities of creating and validating automation tool repository suiting to the need of all sites. This action of *global tool validation* team can help all sites in selecting a suitable automation tool and technology.

Finally, it was discussed that the automation sites also face challenges related to product domain knowledge. Organization leadership should motivate and encourage automation resources to participate in time to time product trainings organized at the other sites. One of the stakeholders rightly said:

> *We do organize trainings for various product components as well as clinical trainings but initiative is needed to involve more people in such training programs*.

Hence, the automation sites need to keep track of domain knowledge trainings organized at other sites and take the initiative to train the automation resources on the needed domain knowledge of the product component.

Improvement needs related to improving communication between sites:

The stakeholders made a suggestion concerning the need of improvement in formal and informal communication between sites. It was agreed in the discussion that there is a big gap existing in communication between the automation resources of different sites. One of the stakeholders proposed improved communication as follows:

> *We need to interact and communicate more with each other to know what other sites are doing. Although we have ample opportunity to learn from each other but we don't really know what kind of knowledge is existing which we can use for our need.*

Hence, the automation sites need to integrate more through communication so that the exchange of information and knowledge can be transferred between sites. A few of the reasonable suggestions that came out of the discussions were as follows:

A practical suggestion came about a *weekly group meeting* for the automation sites. It would be a good start but this idea was a failure in the past due to a difference in the time zones of the automation sites. It was reported that the case company uses restrictions related to participating in group communication from home due to company policy. Hence, it needs commitment from leadership as well as from participants to make these *weekly group meetings* a successful mode of communication between the sites.

Secondly, it was suggested that email chains have a lot of useful information but information is restricted to the participants of the emails. Moreover, people tend to forget the conversations with passing time and it is hard to search and gather old information from emails. A more usable mode of supportive communication like "*Knowledge sharing forum*" could be very helpful to update the other sites with useful information as well as re-use the existing information. This could be helpful for a new resource as well who can go to the forum and search for existing information and knowledge base.

Finally, it was reported that *site visits* by automation resources can also play an important role to create integration and bonding between the sites. At times email conversations and phone calls are not enough to understand everything related to technical conversations. Instead, it is important to visit the site and see how people are actually implementing things. It makes knowledge transfer easier and quick. Hence, communication is an important governance mechanism to facilitate and coordinate knowledge sharing activities between sites.

Thus, all the valuable development ideas from the stakeholders gave an insight of improvement needs as well as practical implications related to existing core issues. These improvement suggestions are the key building blocks towards designing a proposal of knowledge management system for the automation sites.

5.2 Designing a Draft Proposal for Knowledge Management System

The outcome of the current state analysis data revealed a gap in knowledge sharing activity between the automation sites of the case company. Further analysis of outcome data also revealed that challenges faced by each site can be solved by the collaboration of knowledge management activities between the sites. The conceptual framework of the study suggests need of a KM system to facilitate and coordinate knowledge sharing activities between the sites in order to capitalize on the knowledge capital of the automation department .Moreover, the discussions with the stakeholders also lead toward improvement needs in the existing knowledge management system of the automation sites. Hence, the proposal for a Knowledge Management System is based on converging the findings from the current state analysis, conceptual framework of the study and improvement ideas suggested in the discussion interviews with the stakeholders. Figure 17 below gives a diagrammatic overview of the building blocks for designing a proposal of the knowledge management system for the case company.

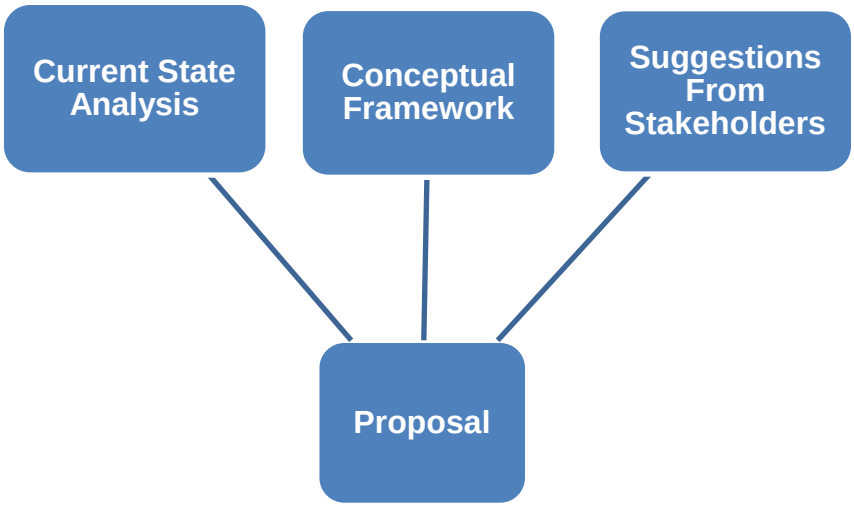

Figure 17. Building Blocks for Proposal

As shown in Figure 17 above, the results of the current state analysis, conceptual framework of the study and suggestions from the stakeholders are condensed together to design a proposal for the knowledge management system for the case company.

5.3 Draft Proposal for Knowledge Management System

As stated in the beginning of this study, the objective of the proposal is to improve the test automation process by designing a framework for capitalizing the scattered knowledge capital of the case company. The proposed knowledge management framework is intended to provide the case company with an organized knowledge repository, efficient knowledge transfer mechanisms and action points for the utilization of the existing test automation knowledge of the automation sites. This new knowledge management framework will eventually improve the maintainability of test automation knowledge as well as enhanced knowledge base of the automation site. Moreover, a successful knowledge management system will also lead to reduced duplicate and redundant tasks which will bring down the work load of the automation sites in the long run. Figure 18 below gives an overview of the proposed knowledge management system for the case company, based on best practice (Section 4) and the analysis of the current state in the 5 test automation sites (Section 3).

Proposal for Knowledge Management System

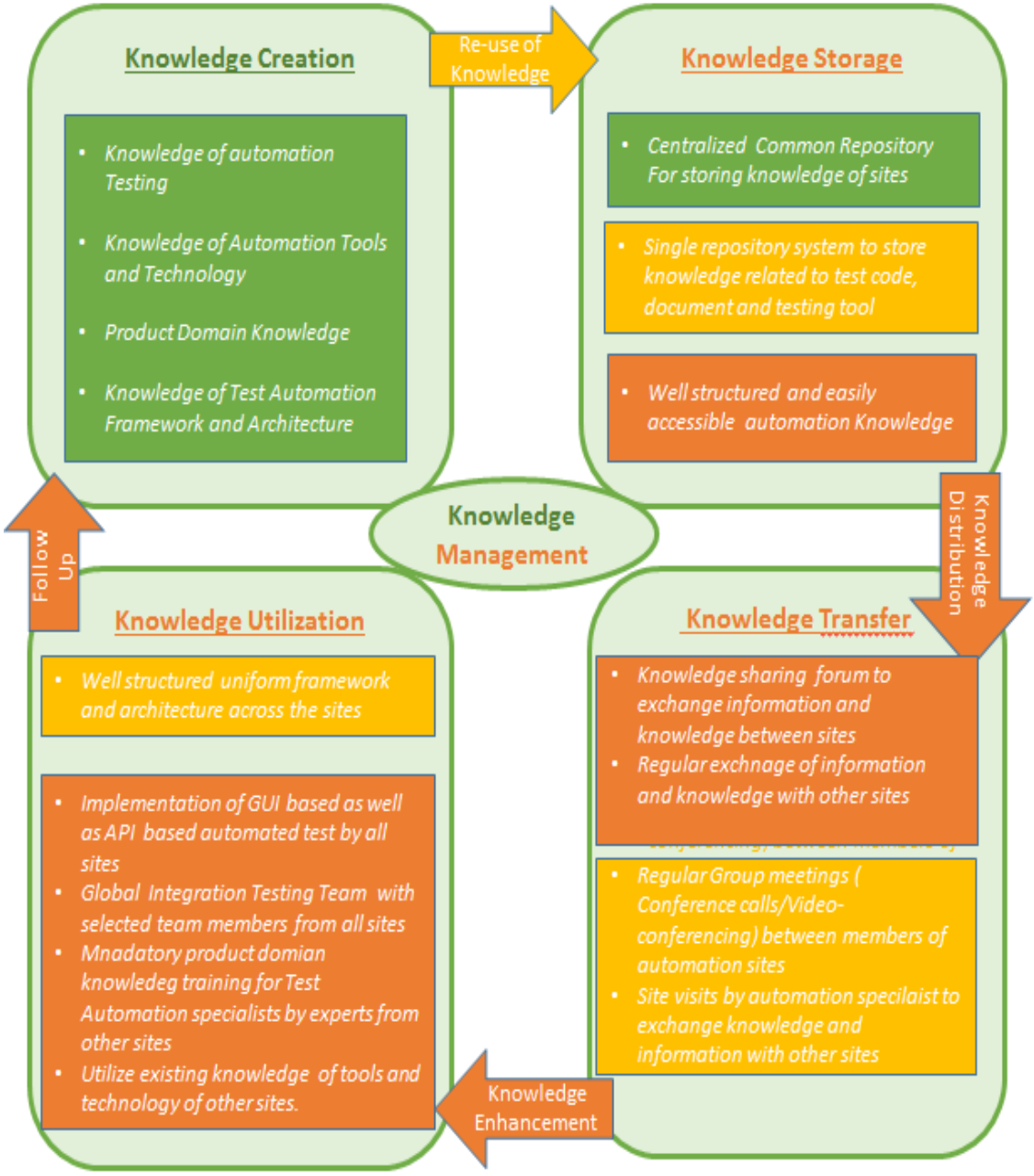

Figure 18. Draft Proposal for Knowledge Management System

Good existing state Work in Progress New Improvements

This study thus proposes that the Knowledge Management System for the automation sites could be looked at as a cyclical process of four phases which includes action points for knowledge creation, knowledge storage, knowledge transfer and knowledge utilization for the automation sites. The green color in the figure above refers to issues which are already in a pretty good condition. The yellow slots refer to actions that have already been initiated. The orange colour refers to the elements that need action.

1. *Knowledge Creation*

The first stage of the knowledge management system is Knowledge Creation phase. The test automation units of the case company already have a very good and stable knowledge creation practice in place but they need a system to capitalize on all existing created knowledge. The automation sites create knowledge related to automation testing, tools and technology used in automation testing as well as knowledge related to product components for which automation tests are created. The automation units of the case company have ample opportunity to create explicit and tacit knowledge related to test automation. Knowledge gets created from individual learning experience as well as from various trainings and documents existing in the test automation sites. The test automation knowledge creation depends on the product components to be tested as well as the test automation need of the development units.

2. *Knowledge Storage*

As the proposal points out, the Knowledge Storage phase is partly secured by a common centralized repository but the case company needs to make many improvements to have a stable, usable and easily accessible storage system. First of all, Automation knowledge created by the automation units needs to be stored in a *single centralized repository system*. All existing knowledge of the test automation units should be transferred to Team Foundation Server (TFS) in order to get rid of multiple repository tools. This will be helpful to maintain the stored knowledge as well as to reduce the duplicate tasks. Other than a single storage system, each site must use a well-structured directory system to store the knowledge so that it is easy to search and re-use the existing knowledge. Finally, the automation units also need to look into the possibility of having an automation team consisting of automation resources from all sites with permissions to grant access rights to other automation resources on the needed automation data. This issue could also be resolved by giving access rights to all automation resources from across the sites on the stored automation data.

3. Knowledge Transfer

In the Knowledge Transfer stage the automation units need to look in to various mechanism of knowledge transfer in order to empower other units to absorb and utilize existing knowledge. To start with, a *knowledge transfer forum* with access rights to all existing resources of the automation sites can act as a good knowledge transfer mechanism. Each automation site can update the forum with important information to share with other sites as well as respond to the issues or help needed by other sites. Knowledge in the forum will be available to all resources and it will be easier to search for information with passing time. Moreover, more frequent group communication through conference calls can be useful to share knowledge with other sites. This will also help to create collaboration and integration between the automation sites. Finally, site visits by the automation resources will give an insight to understand the actual test automation implementation at the other sites. This will be helpful in exchange of knowledge as well as the utilization of knowledge of the other sites.

4. Knowledge Utilization

This stage is the final stage of the knowledge management system. Once the case company has a stable knowledge storage system and knowledge transfer mechanism in place for the automation sites, some action points are needed for the utilization of the existing automation knowledge. First of all, a uniform framework and architecture used by all sites is a long term solution to resolve all existing issues related to the framework. A pilot is in progress to find a solution for a uniform and stable framework for designing automation tests. This pilot is intended to unify the test automation efforts of the sites as well as re-use existing automated tests designed by other sites. For product domain knowledge related issues, mandatory participation in product component training for the automation resources could be useful. Product component training can be organized during site visits and automation resources can participate in group product training at the other sites. Also, a cross functional team consisting of automation resources from all sites with knowledge of various tools, technology and product domain knowledge can help each other in enhancing and implementing the test coverage for API based or GUI based test automation. Moreover, this team can also help with the validation of automation tools suitable for the needs of all automation sites.

Thus, the proposed Knowledge Management System will provide the case company a platform to facilitate and manage the end to end knowledge management activity of the automation sites. This knowledge management system will coordinate the knowledge

related activity of the automation sites starting from knowledge creation, knowledge storage, knowledge transfer until the utilization of transferred knowledge.

5.4 Action Points for Practitioners

Based on the findings of this study, several recommendations can be made in order to implement a knowledge management system for the automation sites. The test automation process of each site is highly complex and unique in nature due to dependency on complex product components manufactured by the sites.

Hence some important action points need to be considered to make knowledge management proposals successful in practice. Table 10 below lists the suggested action points:

Table 10. Action Points for implementation of KM System

Action Points	Implementation Roadmap	Responsibility	Time
Knowledge Sharing Forum for automation sites	• Create Knowledge Sharing Forum (KSF) • Assign Product owner and Key contact person for each site • Update KSF with weekly updates about important information to share with other sites • Link KSF to official email to get notification of updates	Automation Leads of automation sites	6 months
Environmental Factors for supporting Knowledge Management between Sites	• Training for automation resources to train them to implement and contribute to the KM system in their routine day to day work • Periodic communication with automation resources to handle resistance to change mindset • Motivation and awards for key contributors	Management	Continuous Process

Team Foundation Server (TFS) as common centralized knowledge repository	• Transfer all existing automation knowledge to TFS • Re-structure directory structures to mole relevant and uniform for all stored knowledge • Assign contact person at each site to give access rights on automation data of other sites	Automation Team of sites	6 months
Uniform and Stable test automation framework	• Pilot in progress in collaboration with three automation sites to build a solution for uniform and stable framework to support diversified tool and technology needs of automation sites	Automation Resources of three of the automation sites	First release in April,2015

These action points will help to implement knowledge management system as a continuous learning process for the automation sites. Moreover, this learning cycle will act as a building block towards harmonizing the test automation process of the sites in the long run.

5.5 Managerial Implications

If the company decides to take on the project to implement the KM system for the improvement of the test automation process, this study proposes the following prioritization

1. Take a decision to initiate a one year for Test Automation Improvement project and accept the proposed roadmap for it.
2. Nominate a steering group to monitor the progress for the KM system for automation sites.
3. Allocate resources for Knowledge sharing forum, resources for TFS storage training and resources for domain knowledge contact persons.
4. Arrange periodic review and communication with automation resources to highlight their support to make this project successful.
5. Word of appreciation and Rewards for best contributors at the end of project.

Since KM is a complex issue for the scattered organization, the case company may

need to evaluate the outcome of the project at the end of the allocated time frame and need to plan a second phase of the project based on the current performance and status of the KM system at the time of evaluation of the project.

6 Validation of the Proposal

This section takes to data collection 3 of the study which focuses on the validation of the draft proposal for improving the test automation process by implementing the KM system for the automation sites of the case company. This section presents a summary of the feedback from the stakeholders on the draft proposal, final proposal for the KM system and roadmap for implementing the proposal for the case company.

6.1 Feedback From stakeholders on Draft Proposal

The feedback discussion was conducted with the stakeholders of the automation sites on the draft proposal for the Knowledge Management System (KMS) for the sites in order to validate the proposal for the KM system. The feedback session was very meaningful as the stakeholders were well informed about the proposal due to active participation in designing the draft proposal of the study. The discussion was mainly focused on implementation related feedback and suggestions on the proposal. It was commonly agreed by the automation sites to select important building blocks for knowledge storage, knowledge transfer and knowledge utilization to start the implementation of KMS for the automation sites. Based on the feedback from the stakeholders on the draft proposal, the following suggestions came out for the final proposal of the KM system for sites in the case company:

Team Foundation server (TFS) was suggested as an acceptable solution for using *Common Centralized Knowledge Repository* for the automation sites. It was also suggested that the case company, in the long run, should look into the opportunity to combine knowledge from different sources even though the data does not necessarily directly have anything to do with test automation. For example customer complaint data could be combined with test case data to show gaps in testing. That kind of combined data may help for example in planning the content of the proposed product trainings.

Knowledge Sharing Forum was accepted as a good and practical proposal for a knowledge transfer tool by the automation sites. All the sites unanimously agreed to

implement a knowledge sharing forum for improving communication and knowledge sharing activities between the sites.

For effective knowledge reutilization, the stakeholders suggested to assign *Global Integration Testing Team* with selected members from each site. This integration testing team can be assigned to Automate integration scenarios where each member will be accountable for product components from the sites. This will give insight into the integration scenarios of the other sites as well as help foster knowledge sharing and collaboration between the sites.

Finally, it came up during the discussion that *communication* between the Knowledge Storage team, knowledge transfer team and knowledge utilization team need to be established to link the progress of each phase of the KM system to make the implementation successful. Communication plays a key role in syncing the progress of each phase as well as creating collaboration between the phases of the KM system to make the whole system progress towards a common objective.

Thus, all the suggestions and feedback on the draft proposal were very practical and valuable for designing a final proposal for the KM system for the automation sites to improve the existing test automation process in practice.

6.2 Final Proposal for Knowledge Management System

The final proposal for the KM system is built on the basis of the draft proposal and stakeholders feedback suggested on the draft proposal for the KM system described in section 5. Based on the stakeholder's feedback, this final proposal provides a foundation for improving the test automation process by increasing knowledge sharing collaboration between the automation sites. The improved test automation process on the one hand will reduce the work load of each side and on the other hand it will provide the quick solutions to the challenges faced in the knowledge area of other sites. Figure 19 below is the proposed knowledge management system for the case company, based on the draft proposal (section5) and feedback from stakeholders on the draft proposal (Section 6.1).

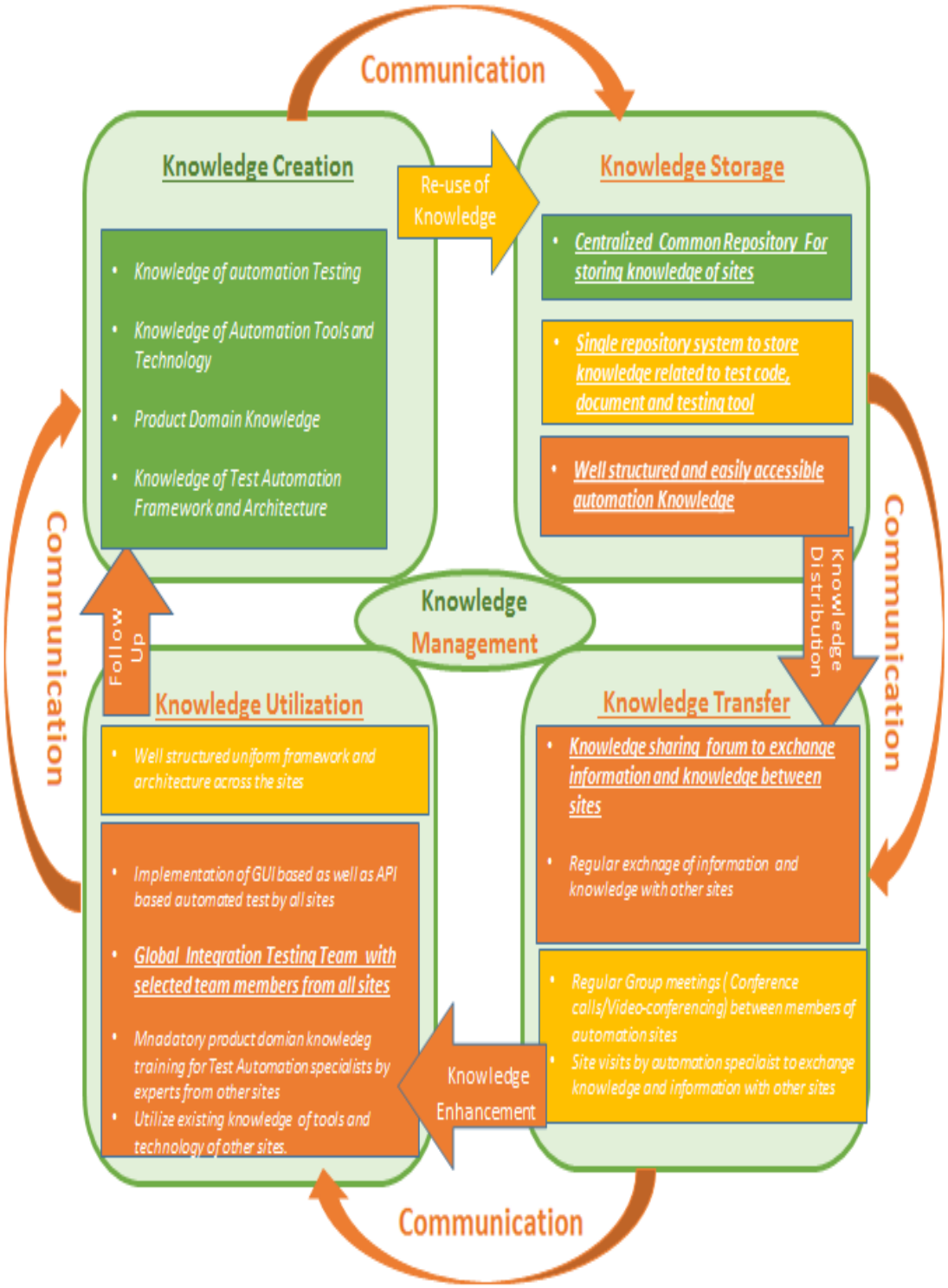

Figure 19. Final Proposal for Knowledge Management System

Figure 19 shows the results of the validation of the draft proposal in brief. The prioritized area decided by the case company for the first phase of implementation of the KM system is shown in block underlined letters in the above figure. Further details of the stages of the KM system are written in section 5.3 of the study as the description of the draft plan for the proposal.

6.3 Road Map for Knowledge Management System

The case company agreed on the implementation of the KM system for the automation sites in order to improve test automation process by managing the test automation knowledge of the sites. This study suggests a roadmap for a successful implementation of the KM system in four phases consisting of Initiation, Implementation, evaluation and corrective measures.

1. Initiation

This phase is an initiation phase for bringing in KM in practice which consists of action points for management of the case company to initiate the Test Automation Improvement Project by sharing knowledge for the automation sites. Management prioritization for initiating the KM system in practice is listed below:

1. Take a decision to initiate a one-year Test Automation Improvement project and accept the proposed roadmap for it.
2. Nominate a steering group to monitor the progress for the KM system for automation sites.
3. Allocate resources for creating knowledge sharing forum, resources for TFS storage training and resources for domain knowledge contact persons.
4. Arrange periodic review and communication with automation resources to highlight their support to make this project successful.

This phase thus grounds the baseline for the implementation of the KM system for the automation sites to improve the existing test automation process.

2. *Implementation*

This is the second phase of the implementation of the KM system in practice which consists of action points for the automation teams of the scattered development units. Table 11 below describes the guideline for implementing the KM system by implementing building blocks for knowledge storage, knowledge sharing and knowledge utilization

measures in practice by the automation sites.

Table 11. Action Points for Implementation of Knowledge Management System

S.N.	Action Points	Implementation Roadmap	Responsibility	Time
1.	Team Foundation Server (TFS) as common centralized knowledge repository	• Assign Key contact person for each site for TFS • Transfer all existing automation knowledge to TFS • Re-structure directory structures to mole relevant and uniform for all stored knowledge • Assign contact person at each site to give access rights on automation data of other sites • Communicate with Knowledge Transfer Team and Integration Testing team to sync and link the progress.	Automation Team of sites	1 year
2.	Knowledge Sharing Forum for Knowledge Transfer between sites	• Create Knowledge Sharing Forum (KSF) and assign a product owner. • Create Knowledge transfer team and assign Key contact person for each site • Update KSF with weekly updates about important information to share with other sites • Link KSF to official email to get notification of updates • Communicate with TFS team and Integration Testing team to sync and link the progress.	Automation Leads of automation sites	1 year
3.	Integration Testing Team for Utilization of Existing Knowledge of other sites	• Create common global team with objective to create automated tests of integration scenarios • Allocate selected members from each sites where each member will be accountable for his or her site's product component • Create automation tests for workflows and clinical scenarios • Communicate with TFS team and update Knowledge sharing forum with progress to sync and link the progress.	Automation team of automation sites	1 year

As illustrated in Table 11 above, the implementation phase suggests a roadmap for establishing the KM system for the automation sites by designing a common repository, creating Knowledge Sharing Forum and forming a global Integration testing team for the automation sites. This will help the automation sites to increase the knowledge sharing collaboration with the other sites by capitalizing on knowledge created by the sites which can be reutilized by all sites.

3. *Evaluation*

This phase is the third stage of the implementation of the KM system which consists of evaluation action points for both the management and test automation team. The management and test automation team representatives should sit together at the end of the allocated time frame to evaluate the outcome of the “Test Automation Improvement Project”. The Action Points for the evaluation team are mentioned below:

1. Performance and status evaluation of the KM system at the end of allocated timeframe.
2. Analysis of strengths and challenges faced during the implementation phase of the KM system for case company.
3. Word of appreciation and Rewards for best contributors at the end of project.

Hence, this phase is retrospective for the implementation phase which helps the management team to take a decision about future plans for the existing KM system in the case company.

4. *Corrective Measures*

This is the last phase of the implementation roadmap for the KM system. This phase consists of action points for the management team to take corrective measures for a successful implementation of the KM system:

1. Identify concerned department or experts who can contribute towards finding solution for challenges faced during implementation phase.
2. Take corrective actions for the lists of challenges discussed during the evaluation phase
3. Plan a second phase of the test automation improvement project with suggested corrective measures.

This phase is the final stage of the test automation improvement project which lays the building blocks for the next cycle of the KM system for continuous improvement of the

test automation process of the scattered automation sites.

Hence, the KM system will eventually lead the case company towards an improved test automation process by fostering collaboration and knowledge sharing between the sites for a common organizational goal. Moreover, the KM system will contribute as a foundation step towards harmonizing the test automation process for the scattered automation sites in the long run.

7 Discussion and Conclusions

This section presents a summary of this study, analyzes success in achieving the objective and evaluates the reliability and validity of the study.

7.1 Summary

The objective of this study was to improve the test automation process of a globally scattered multinational organization by building a KM system to facilitate knowledge sharing activity between the automation sites. The case company of this thesis is a US based medical device manufacturer having development units scattered across the globe. Each development site of the case company has a test automation unit which is very rich and specialized in existing knowledge assets needed for that department. Although the automation sites manage efficiently their tasks which require expertise from local knowledge they face challenges if the tasks require application of knowledge from other areas and product components which are not manufactured locally at that site. Hence, the case company faces a need for a central knowledge management system to facilitate collaboration in knowledge sharing between the sites which will eventually lead to an improvement of the test automation process of the sites.

The current state analysis conducted on the automation departments of the sites revealed that the organization is facing difficulties to use site specific local knowledge bases to address the knowledge need of the other sites. The draft proposal of this study is the KM system to centrally capitalize on and manage the knowledge asset of the sites. The proposed KM system was designed based on best practice from literature as well as improvement suggestions from the stakeholders to improve the knowledge sharing activity between the sites. The draft proposal was validated with the stakeholders of the sites which helped to design an improved version of the KM system to address the concerns and feedback of the automation sites. The final model of the KM system suggests various action items and a road map to store the existing knowledge base of each automation site and share the centrally stored automation

knowledge between the sites to address the challenges and knowledge need faced by each site.

Hence, the outcome of this study is a KM system for the integration of knowledge related activity between the sites. The proposed KM system will contribute towards improving the test automation process of the organization by reducing duplicate work done by the sites as well as providing a quick fix for problems which need expertise and knowledge from the other sites.

7.2 Outcome vs Objective

The objective of this study was to propose a roadmap for an improved test automation process by sharing knowledge between sites. The proposal of this study was drafted in collaboration with the automation sites for the improvement of knowledge management activities between the automation sites. This thesis then proposed the final recommendation and action plan for the improvement of the automation process by bringing in the KM system in the organization which addresses the concerns and feedback from all sites.

Thus, the outcome of this study is a KM system which can improve the test automation process by converging the existing automation knowledge of the case company and reutilize the existing knowledge by all automation sites to achieve the organizational goal. So, the result of this study provides the proposal for the KM system which satisfies the research objective of the study to suggest a roadmap for improving the test automation process by sharing knowledge between the sites. Hence, to conclude the study, it is justified to say that the outcome of this study is successful in achieving the objective set in section 1 for this study.

7.3 Reliability and Validity

As described in Section 2.5, the validity and reliability in this study were considered during the writing of this thesis by taking a number of different measures.

To secure the validity in this study, the researcher got several informants with different kinds of roles and responsibilities from the automation sites involved in data collection in order to get authentic data for this study. The researcher also examined internal company documents and test result data of the automation sites to verify the correctness of the information coming from various informants to provide triangulated data.

In order to achieve reliability in this study the draft proposal was re-verified with the existing informants and also got some new informants involved at a later point of time to add trustworthiness and authenticity to the findings of the study. The informants also had the opportunity to provide feedback on the draft proposal to ensure that the interpretation of data was done correctly. Hence, this study takes into consideration the essential criteria to make this study reliable and valid.

Although the study takes into consideration important essential criteria to make the study valid and reliable, it still faces some challenges in terms of validity. Firstly, the study faces some challenges in terms of neutrality caused by the researcher's own bias due to 9 years of involvement with the test automation process of the case company. Although there was an effort to carry out the research in a neutral way, the researcher's own bias impacted the study during data collection as well as during data analysis due to existing knowledge and experience of the subject under study. At the same time, it is also needed to be considered that the involvement of the researcher with the subject under study provided an opportunity to understand the subject from various perspectives as well as gave access to ample information related to this study which was very significant for carrying out this research. Secondly, due to a limited research period it was not possible to validate the suggested roadmap for improving the test automation process for the case company by practically implementing it. Moreover, it would be interesting to evaluate the proposal in terms of process cost reduction for the automation sites after the implementation of the Knowledge Management System in practice.

At the end it can be said that this study provided an interesting topic for future research since it relates to the knowledge management challenge faced by several distributed organizations in the current global and dynamic business environment. Scattered organizations face innumerable challenges in managing existing knowledge assets due to a lack of collaboration and relationship between different sites which causes major pitfalls and gaps in services in the organization. Efficient Knowledge Management (KM) can keep scattered sites of such an organization well aligned and linked with each other which results in making the work loads of sites easier and faster. Moreover, knowledge collaboration also fosters the knowledge bridge between sites to increase the quality of service delivered by the units by the exchange of specialized and distinct skills sets.

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Appendix 1

Current state analysis Phase: Discussion Interviews (Data 1)

Interview Question Sample

S.N.	**Questions**
1	How automation department is involved in project selection procedure for test automation?
2	What tools and technology is used for automation projects in this automation division?
3	What kind of Test automation framework and architecture is used for automation projects?
4	How decision is taken about tools, technology or architecture to be used for a particular test automation projects?
5	What kind of documentation process is followed for test automation projects?
6	What kind of practical challenges is faced with current test automation process in practice?
7	What kind of challenges is faced with respect to deadlines for test automation projects
8	What kind of collaboration exists with other test automation sites?
9	What kind of difficulties is faced while dealing with automation sites of other development unit?
10	How do you manage Integration testing efforts?

11	What Kind of process is followed for tool validation for formal testing process?
12	How do you maintain old implemented automation projects?
13	What kind of reporting tools we use to reporting results of automated tests?
14	What are the strengths of current automation process?
15	What are the areas of concerns or problems existing with current test automation process?

Sample Field Note abstract from one of the Interview Discussion

Interview Questions	**Answers**
How this automation department is involved in project selection procedure for test automation?	Test automation department is responsible for taking decision of selecting requirements suitable to be automated for that particular project. Automation leads along with product manager and take a decision on finalizing the selected project requirements to be automated.
What kind of tools and technology is used for automation projects in this automation division?	There is no clear cut path or guidelines for tools or technology to be used for automation projects. We do have a tool repository for automation projects. Normally , we do pilots to find the suitable automation tools and technology to be used for that particular automation project
What Test framework and architecture is used	Process and architecture differs from project to project as every single project is unique in nature and it is very hard to stick

for automation projects?	to single architecture for every project.
How do we take decision about which tools, technology or architecture to be followed for test automation projects?	Test automation lead takes a decision on the architecture to be followed for that project. Regarding tools and technology, automation specialist involved with doing pilot for the project takes decision on tools and technology to be used for that project.
How do you manage audits using so many tools and technology considering the strict specifications like FDA (Food and Drug Administration, USA) audits?	We use automated projects for informal testing which saves us from coming in the boundary of FDA audits up to large extent. We are slowly moving towards Microsoft supported package which enables to implement automated project which will help us to sync with product code as well as audit standards. We already have implemented some projects using Microsoft supported test automation tools and tests are stable and consistent as well.
What kind of documentation process is followed for test automation projects?	We do have architecture documents from the implemented test automation projects. We will share the location and other details about that document on email after this meeting. Other than that we generate reports from the test to share the result with managements , we can share the a sample report but just to warn that report is in basic format not much extra features like graphs and charts for failures or passed test cases.
What kind of challenges do we face with current test automation process in practice?	There are many challenges but complexity of the application to be automated is major challenge as one standard way does not work with other. We also need to rewrite many of the standard documentation while using other automation tool than the current one which creates extra work for us. Another important issue we are facing is continuous change in technology which creates compatibility issue with existing automation tool in use.
What kind of collabora-	There is very little collaboration exists with the automation de-

tion exists with other test automation sites?	partment of other site. I visited the other automation site last year, it was very fruitful visit and we agreed for increased collaboration but then nothing concrete happened.
What kind of difficulties you face while dealing with automation sites of other development unit?	Collaboration with other sites must increase as at times it creates issue with deadlines if information is needed from other site. There is no clear cut information globally available who to contact for that particular issue so the mail goes in rounds to find the right contact person. Time zone also is an issue to quick needed information on time even though some resources are extremely helpful and willing to help out with the needed information or help.
How do you manage Integration testing efforts?	We do not have automated tests for integration testing. We have manual tests and struggle during every project to execute it for every release.
What Kind of process is followed for tool validation for formal testing process?	We do tool validation for neither informal testing nor formal testing. We follow the process as described in global tool validation specification document. We will share the location of tool validation documents in document repository, which you can go through for further details.
How do you maintain old implemented automation projects?	Automated projects are saved in version control for that particular released branch and a separate branch is created for new release. It makes maintenance very easy if we need to run automated test for old projects. We just need to check out the tests for that version and run against it.
What are the strengths of current automation process?	We do not invest much time in pilot testing for automation project as we have good knowledge about tool compatibility with product and technology. We also have documents available about the same which we can share with other automation sites if other sites are interested. Another important thing we would like to highlight that automated tests are very stable as the tests are data driven where test scripts have no hardcoded

	data, data is stored in data files which helps to maintain the tests without much changes.
What are the areas of concerns or problems existing with current test automation process?	There are many challenges but complexity of the application to be automated is major challenge as one standard way does not work with other. We also need to rewrite many of the standard documentation while using other automation tool than the current one which creates extra work for us. Another important issue we are facing is continuous change in technology which creates compatibility issue with existing automation tool in use.

Appendix 2

Proposal Phase: Stakeholders Discussion (Data 2)

Stakeholder Discussion Abstract

Discussion Agenda	Discussion Details / suggestion
What kind of benefits will serve to our automation department if we collaborate in our efforts?	This is clearly a long time due agenda which needs to implemented now which will benefit the automated sites. It will save lot of our time and effort as well. This will help us with our integration testing efforts which is always tricky for every site as well knowledge can be shared with respect to tools, technology existing automated tests for the product components. Although we have been talking lot much in every other global meet and we are aware of the same but still implementation does not take place due to lack of clear cut work procedure for the same. We think about collaboration only when we are in trouble or in need of other site knowledge and it is true with every other automation sites.
Threats or concerns exist in collaboration efforts of test automation departments?	We would not like to follow any common structured process as it will restrict our freedom to select best possible option for the automation project. We do believe in agile way of working where we select best suited change for that particular situation hence it is very hard to collaborate the effort. Also its very difficult to get agree on a particular automation tool or framework to be adopted since a particular tool giving excellent result for one could be failure for another. Also, the global way of working is very time consuming which will take reasonable amount of time and effort to get every site tuned and synced with each other. For some site process is mandatory to be followed where as for other work culture it is completely different and they might feel strangled with process restriction. Overall, it is very challenging to bring every site at same plane so we have a challenging path ahead to implement collaboration.

What kind of efforts can be taken to centrally store test automation knowledge set so that it can be accessed by other sites?	There are long lists of improvement suggestions. Improving the repository system is priority for the collaboration efforts as duplicate and scattered knowledge and information exists with different repository. All automation sites uses TFS (team foundation server) for saving automated scripts and test data but every site uses their own structure and naming conventions for saving test automation projects. It is hard to get agree on common structure pattern because the structure is dependent on product package structures saved in TFS (Team Foundation Server). Also it is very inconvenient and takes waiting time to get access on the automation projects saved by other site since all automation resource do not have information about whom to contact for access.
What measures can be taken to improve the collaboration between automation sites?	Communication gap is a clear area which needs to be worked on for improving the collaboration. We need to interact and communicate more with each other to know what other sites are doing. Although we have ample opportunity to learn from each other but we don't really know what kind of knowledge is existing which we can use for our need. A weekly meeting is a good idea but the idea failed in past as automation sites stops participating slowly with passing time due to lack of common interest. Time zone as well is obstacle in such collaboration effort as it is very hard to find suitable common timing for such meetings. Other mode of communications like instant chat is helpful only if all participants are available online sometime and we do have constraints due to company policy automation resources do not have work from home facility. So only active way of interaction is email which has so many drawbacks. It is very hard to know whom all to include in participant lists in our email chain and after certain period of time we do forget what we have interacted over email. Other than this new comers do not have access to information discussed in past over some email chains. To overcome all these challenges Knowledge Sharing Forum is a good idea which can be used as communication means for collaboration efforts. Each site can take responsibility update the forum with important information to be shared with other site as well as help other site with needed information. This will also help to have all information intact and stored in

	the forum which anyone can find very easily even after months or years.
What are the existing possibilities to utilize existing test automation knowledge related to tests, product domain, tools and technology with other automation sites?	It is not a very easy to utilize existing knowledge base as it is because knowledge is so tightly glued with the local work culture, architecture, system dependency on local set up and factors like localized way of implementation. This makes it almost impossible to replicate the knowledge at other site at their environment. Site visits can be helpful in such cases as it can give an opportunity to see how actually things are getting done in run time. An integration testing team consisting specialist from all sites could be a good start to understand the details of practical issues we need to fix while dealing with such collaboration efforts. Whereas sharing information related to tools and technology is concerned, it can be done without much hassle since some or other kind of documents exists for the validations done for tools and technology to be utilized in test automation projects. Product domain knowledge is also not a constraint as we do organize trainings for various product components as well as clinical trainings but initiative is needed to involve more people in such training programs. We need to start progress slowly in this regard, once we are successful in fostering base of collaboration ,we can improve it eventually with due course of time.

Appendix 3

Proposal validation Phase: Feedback Session (Data 3)

S.N.	Feedbacks
1	Idea of Knowledge Management is very good we can move ahead with it. Concept of knowledge management system is very good and it should address many of the existing challenge of knowledge sharing system. Although We cannot implement Whole system at a time so need to move slowly and pick the first buildings block from suggested proposal.
2	Communication between different phases of knowledge management system is needed in the suggested proposal else it is impossible to sync the progress. Failure of any of the phases can impact the whole system, hence it is important the each of the phase communicate and update regularly with the representatives of other phases. KSF (Knowledge Sharing Forum) can be utilized to sync the progress of all phases together. Some of the sites have some past experience related to KSF, hence it should be doable and can be implemented without investing much time and effort.
3	We can work towards making team foundation server (TFS) more unified and easily accessible for all sites. At presents although we all use TFS but its impossible for other sites to access and utilize is in current format. Long due improvement, we must start acting towards improving the TFS storage system.
4	To utilize existing knowledge base, Global Integration Team would be a good idea. We need to identify the resources from every site who can contribute towards making tests for end to end integration testing for the product package
5	Once we get the results of the first round of implementations of knowledge management system (KMS) in practice , it will help us to access and make future plan of action related to KMS.