THE IMPACT OF FOLLOWING AUTOMATED TESTING LIFE-CYCLE METHODOLOGY (ATLM) ON THE SUCCESS OF FUNCTIONAL TEST AUTOMATION - AN OVERVIEW OF THE SRI LANKAN SOFTWARE INDUSTRY

Devinda Pathirannehalage Manori Madubhashini Wijesooriya

(189130T)

Degree of Master of Business Administration in Information Technology

Department of Computer Science and Engineering

University of Moratuwa

Sri Lanka

July 2021

THE IMPACT OF FOLLOWING AUTOMATED TESTING LIFE-CYCLE METHODOLOGY (ATLM) ON THE SUCCESS OF FUNCTIONAL TEST AUTOMATION - AN OVERVIEW OF THE SRI LANKAN SOFTWARE INDUSTRY

Devinda Pathirannehalage Manori Madubhashini Wijesooriya

(189130T)

The dissertation was submitted to the Department of Computer Science and Engineering of the University of Moratuwa in partial fulfillment of the requirement for the Degree of Master of Business Administration in Information Technology.

Department of Computer Science and Engineering

University of Moratuwa

Sri Lanka

July 2021

DECLARATION

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Also, I hereby grant to University of Moratuwa the non-exclusive right to reproduce and distribute my thesis/dissertation, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).

……………………………… 2021-07-22

D. P. Manori M. Wijesooriya Date

The above candidate has carried out research for the Masters thesis under my supervision.

Indika Perera
2021.07.24
17:06:13 +05'30'

……………………………… ………………………

Dr. Indika Perera Date

COPYRIGHT STATEMENT

I hereby grant the University of Moratuwa the right to archive and to make available my thesis or dissertation in whole or part in the University Libraries in all forms of media, subject to the provisions of the current copyright act of Sri Lanka. I retain all proprietary rights, such as patent rights. I also retain the right to use in future works (such as articles or books) all or part of this thesis or dissertation.

………………………………

D. P. Manori M. Wijesooriya

ABSTRACT

Functional test automation is a very important and trending software testing technique which enables achieving improved efficiency, accuracy and coverage of testing. Automated Testing Life-cycle Methodology (ATLM) is the systematic process used in the test automation. As following a proper process is important to achieve success in any task, it should be applicable for test automation also. Hence it is crucial to follow ATLM in test automation in order to achieve a success in it.

Therefore, this research intended to identify the impact of following ATLM on the success of test automation in IT industry in Sri Lanka.

This study was conducted as a quantitative research by collecting data from Quality Assurance professionals in Sri Lankan IT industry as it was considered as the sample here. Data collection was done with an online survey with Voluntary Response Sampling technique by reaching out to the potential survey respondents. Data analysis was done with the IBM Statistical Package for the Social Sciences (SPSS) tool. The distribution of the sample was analyzed with the descriptive statistics techniques. The Analysis of Variance (ANNOVA), Pearson's Product-Moment Correlation and Multiple Regression analyses were done as inferential analysis.

As per the results of data analysis, 4 steps out of the 6 steps in ATLM namely *"Decision to Automate Tests"*, *"Test Tool Acquisition"*, *"Automation Testing Introduction Process"* and *"Test Planning, Design and Development"* are highly impacting on the success of test automation while the other 2 steps namely *"Execution and Management of Tests"* and *"Test Program Review and Assessment"* are having a medium level of impact.

Therefore, this study concludes that following ATLM has an impact on the level of success of test automation in the IT industry in Sri Lanka.

Keywords: Software Test Automation, Automated Testing Life-cycle Methodology (ATLM), Success of Test Automation, Software Testing in IT industry in Sri Lanka

ACKNOWLEDGEMENT

This thesis is a final outcome of assistance and guidance from several parties. First of all, I would like to extend my gratitude to my research supervisor Dr. Indika Perera for his guidance, immense support and encouragement throughout this research. Also, I would like to thank Dr. Kutila Gunasekara for the guidance given as the course coordinator of MBA in IT 2018 batch.

Furthermore, my I would like to thank all the Sri Lankan Software Quality Assurance professionals who spent their valuable time on responding the survey questionnaire as well as the people who helped me to reach out to potential survey respondents through their contacts. Their support was really important to make this research a success. Also, I would like to thank all the researchers who have done their study in the areas related to this research as it was greatly beneficial in this research study

Moreover, I would like to thank all the batch mates in MBA in IT 2018 batch who shared their knowledge of the research process. Also, I would like to thank Mr. Samila Hapuarachchi for sharing his knowledge of statistical data analysis and the guidance given on data analysis and interpretation. Finally, it is a pleasure to express my gratitude to my family members and colleagues for their support and encouragement which helped me to complete this research successfully.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

ATLM - Automated Software Testing Life-cycle Methodology

BPM - Business Process Management

CSF - Critical Success Factors

DV - Dependent Variable

ICT - Information and Communication Technology

ICTA - Information and Communication Technology Agency

IT - Information Technology

IV - Independent Variable

QA - Quality Assurance

ROI - Return on Investment

SQA - Software Quality Assurance

STLC - Software Testing Life-cycle Methodology

SUT - Software under Test

1. INTRODUCTION

1.1. Background

In the Information Technology (IT) industry, Software Quality Assurance (QA) plays a vital role similar to software development. QA is a key action engaged all the way through the life-cycle of software development in order to guarantee the quality of the software. As a part of the QA process and scope, functional testing of the developed software is being done at the software testing stage by executing real user scenarios on the Software under test (SUT) in order to make sure that there are no breaks in the real user access flows. The objective of ensuring the quality of software can be achieved by doing the testing manually by human beings as well as through software test automation.

Following a well-defined process in the software testing and QA is crucial for delivering high-quality software to the customers and end-users. As stated by Pettichord (2001) following a well defined process will lead to save some time to be spent on manual testing and therefore, it will help to continue the test automation efficiently and smoothly. Test Analysis, Test Planning and Designing, Test Execution and Reporting are the main stages of a formal software testing process (Eriksson, 2016). However, there are several definitions for the QA/testing process and different models have been developed including the content of these mentioned 4 stages. Similar to manual testing, it is important to define the scope of testing, have well organized test suites with a proper design, execute the tests and report the test results accordingly in test automation also. Automated Testing Life-cycle Methodology (ATLM) is the structured approach dedicated for software test automation. More details of the ATLM are described under the topic 1.1.1 Automated Testing Life-Cycle Methodology (ATLM)).

There are companies who are doing test automation in Sri Lankan IT industry. But it is questionable whether they are following a defined process knowingly or unknowingly, whether they are getting the real benefits out of automation and also whether following a defined process is having an impact on the success of automation.

1.1.1 Automated Testing Life-Cycle Methodology (ATLM))

Automated Testing Life-Cycle Methodology consists of 6 stages as depicted in figure 1.1.(Dustin, Rashka and Paul, 1999)

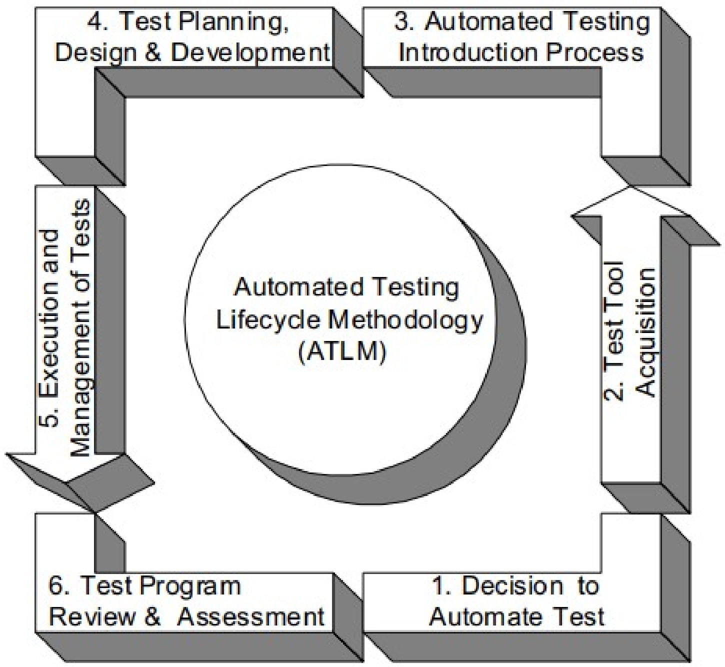

Figure 1.1: Automated Testing Life-cycle Methodology(ATLM)

The first stage "Decision to automate test" focuses on identifying the feasibility of automating the tests and decision making. It considers the every aspect including which modules/functions can be automated and which not, which tests can be automated and which not, how to automate them, and some other factors such as the size and the expertise of the team and the cost. (Dustin, Rashka and Paul, 1999)

The next stage "Test Tool Acquisition" is also a critical phase in ATLM since automation is highly depending on the tool. Budget, knowledge or experience of the team members on the tool, technologies used in the project are some of the factors to be considered at the tool selection. (Dustin, Rashka and Paul, 1999)

The third stage "The automated testing introduction process" is focusing on the analysis of test process considering the goals, objectives and strategies, whether the test process is documented and communicated to the team or not and analyzing the test requirements and planning the test activities. Further, test tool compatibility with the application under test and mapping the tool with testing requirements are also considered here. (Dustin, Rashka and Paul, 1999)

The next stage is "Test Planning, Design and Development". Creating the test procedure, test data, hardware, software, network, test schedule, roles of team members, risks and contingencies, defect tracking procedure are considered as test planning. As the test designing, paths and functions that tests will be approached, test conditions, test design standards, test architecture are considered. Reusability, maintainability, repeatability, development standards and procedures are considered under the test development. (Dustin, Rashka and Paul, 1999)

"Execution and Management of Tests" is the next stage in ATLM which focuses on complying with test procedure execution schedule, documenting the test results and evaluating the outcome considering the metrics for test coverage, progress and the quality of the test effort. (Dustin, Rashka and Paul, 1999)

The final stage of ATLM is "Test Program Review and Assessment" However, this need to be conducted throughout the testing life-cycle. Metrics to be evaluated, identifying the process improvements with final review and assessments, reviewing the performance of entire automation project, assessing the effectiveness in order to evaluate the ROI are the main considerations in this stage. (Dustin, Rashka and Paul, 1999)

1.2. Motivation

In today's world, test automation is having a high demand in the QA domain in the software industry. It has become a norm as test automation is giving much more benefits than manual testing and therefore, most of the companies are moving towards automation by adapting various automation techniques.

However, there are some IT Companies who have experienced test automation failures due to several prominent reasons including lack of technical expertise, not identifying what to be automated and what not, not selecting suitable tools and techniques.

Even though a systematic approach is out there as ATLM dedicated for test automation, it is questionable the awareness of Sri Lankan QA community about this concept. However, there could be some organizations following the steps included in this methodology knowingly or unknowingly.

Therefore, it is worthwhile to investigate the impact of following the ATLM on the success of the functional test automation. Uncovering this fact will be beneficial for the IT organizations in Sri Lanka.

1.3. Research Scope

The purpose of this study is to identify whether following the "Automated Testing Life-cycle Methodology (ATLM)" is having an impact on the success level of functional test automation in the IT industry in Sri Lanka. The target audience or the population of this study is the Software Quality Assurance (SQA) professionals in the IT industry in Sri Lanka. The data is gathered from SQA professionals with the aim of identifying how they are performing actions related to each stage in the ATLM and what is the level of success of the test automation in their organizations. The study was carried out during the year 2020.

1.4. Statement of the Problem

Testing is an expensive and effort-intensive step in a software development project. As per the research done by Vahid & Frank, the global costs for QA including testing the software, hardware, and services calculated to be 79 billion Euros in 2010. Therefore, it is crucial to automate software testing in order to achieve the cost effectiveness over manual testing.

In addition to the cost effectiveness; efficiency, fast and early identification of defects, increase in test coverage and confidence level are the benefits achieved by test automation while the cost, lack of skilled resources and management support are the major challenges faced by IT organizations in Sri Lanka.(Hushalini et al, 2014)

With test automation, same testing steps done by a human being in manual testing are supposed to be carried out with an automated script or a tool. Therefore, it is important to follow a proper process in the test automation similar to the manual testing. ATLM is a systematic approach available for test automation.

Hence, the research question would be;

Does following Automated Testing Life-cycle Methodology (ATLM) have an impact on the success of functional test automation in the IT industry in Sri Lanka?

1.5. Research Objectives

This research study aims to achieve the following objectives

- Identify whether the ATLM is followed by the IT organizations in Sri Lanka.
- Assess the level of success in test automation in IT organizations in Sri Lanka.
- Identify the correlation between ATLM and the level of success in test automation.
- Identify the key factors affecting on the success of test automation in IT organizations in Sri Lanka.

1.6. Research Significance

There is a vast number of research studies done related to software test automation by scholars and several important factors are revealed by them. Most of them are focusing mainly on identifying the success factors of test automation and challenges faced in test automation in the software industry.

Further, when it comes to software QA domain in Sri Lankan IT industry, just a handful of research studies have been conducted and they also mainly focus on the success factors and challenges faced by automation teams. Even though a systematic approach is out there as ATLM tailored for automation testing, it is very limited that this approach (ATLM) is discussed or subjected in research studies done in the SQA domain especially in the Sri Lankan IT industry.

Therefore, it is worthwhile to investigate whether the ATLM is followed by QA professionals, and whether it has an impact on the success of test automation in Sri Lankan IT industry.

1.7. Outline

This thesis is structured as follows;

Chapter 2: Literature Review

This chapter summarizes the literature assessment done on the research area of software QA focusing the functional test automation and identifies the gaps in the literature.

Chapter 3: Research Methodology

An overview of the research methodology followed in this study is discussed in this chapter. It includes the details on Conceptual Framework, size of the population and the required sample for this study and the design of the questionnaire.

Chapter 4: Data Collection and Analysis

This chapter describes the data collection approach followed and the challenges encountered during the data collection. Further, it mentions how the collected data was cleansed and fed into data analysis tools used.

Chapter 5: Conclusion and Recommendations

Conclusion and the recommendations derived from the data analysis are explained under this chapter. In addition to that, the limitations in this research study are also discussed there. Further, some future work identified during this study is proposed at the end of this chapter.

2. LITERATURE REVIEW

2.1. Importance of Test Automation

Now-a-days web applications are becoming more popular due to the services that they are providing especially in the financial and commercial sector. The widespread use of web applications demands for their quality levels. (Leotta, Clerissi, Ricca, & Tonella, 2013)

As per the study done by Hooda and Chhillar, Functional Testing, Performance Testing and Security Testing are the three main types of testing where all the testing types of software systems can be categorized. There should be a right mix of functional, performance as well as security testing in order to ensure the quality of a software system. However, functional testing is the first and foremost aspect out of these three main types. (Hooda & Chhillar, 2015) Since functional testing is essential for ensuring the quality of software, it is important to have efficient ways of doing functional testing. Improving testing process effectiveness and the quality of software also helps to reduce software costs in the long run. Test automation is a technique which can be used to improve the efficiency of functional testing. (Kasurinen, Taipale & Smolander, 2009)

Automating Graphical User Interface (GUI) testing primarily solves the cost and speed problems moreover improving the quality because automated tests increase the frequency of test execution and it helps to identify the bugs faster. However, that advantage could be achieved only if that particular scenario is covered by the automation (Leotta, Clerissi, Ricca, & Tonella, 2013). Further, in this study it is revealed that scripting done in the test automation itself contributes to improve the quality of software since the people who write the script have to execute the test cases multiple times manually in order to get a better familiarity on how to automate those test cases. Therefore, the effort on development itself helps to identify some of the bugs in the software. Any additional bugs being added to the same feature in future enhancements which need regression testing, could be identified with repetitive execution of automated tests.

According to Rouse (as cited in Hushalini et al, 2014) the objective of test automation is to simplify the effort required for testing as much as possible with a minimum effort on scripting. Saving time and money, improved accuracy, increased coverage, ability to do things which are impossible with manual testing, ability to re-run the tests quickly and repeatedly, improving the moral of testers are the benefits of test automation as stated by SmartBear Software. (as cited in Hushalini et al, 2014)

Garousi & Elberzhager (2017) have mentioned that latest software development methodologies such as agile methods and continuous integration promote test automation not only at software test execution but during the software development, deployment and delivery stages also.

Saher, Khan, Shahzad & Karim (2015) have identified some benefits of test automation. Reliability and reusability are two of them. It is possible to have a thorough coverage of test scenarios via test automation. It will require a considerable time to implement the logic of the test cases. However, the execution time will be less compared to the manual execution.

2.2. Impact of a Testing Process on Success of QA

Pressman has stated that (as cited by Hooda & Chhillar) test plan, test data and test environment preparation have to happen at the test preparation phase. It is important to have a test plan since it outlines the scope, objectives, features which should be tested and the features which are not needed to be tested, types of testing to be performed etc.

Different testing techniques are used to test different software applications while different development models are used to develop them. Companies are modifying their testing processes as per their requirements and the testing is conducted based on the criticality of the application. (Hooda & Chhillar, 2015) The main phases of a standard software testing process are analysis, planning & preparation, execution, and closure.

Test environment preparation is one of the most important phases. When it comes to test automation, the test environment matters a lot because any testing has to happen in an environment almost identical to the client's environment.

As concluded by Kumar and Mishra (2016) the effectiveness of the overall testing process is increased when there are similar testing tasks to be executed repeatedly.

Saher, Khan, Shahzad & Karim (2015) have pointed out that the testing process is made up of the activities such as test planning, designing, implementation, execution and evaluation.

As specified by Kasurinen, Taipale and Smolander (2010), enhancing the software quality and effectiveness of the software testing process helps to reduce the cost of software.

2.3. Impact of a Testing Process on Success of Test Automation

Bret Pettichord has identified seven key steps for achieving success with test automation. Improving the testing process is the first item in his list. (Pettichord, 2001)

Similar to the manual testing, setting up the pre-conditions, comparing the actual outcome with the expected outcome and then documenting the actual outcome and observations based on some standards need to be happened in the process of test automation.(Kumar & Mishra, 2016)

It is proven that effective decisions on automating the integral testing process including designing test cases, test scripting, execution of tests and evaluation of test results, may result over 100% ROI (Return on Investment) in around ten test execution rounds. (Amannejad et.al, 2014, as cited in Kumar & Mishra, 2016)

As per a case study done by Leotta, Clerissi, Ricca, & Tonella (2013) it is not possible to automate even all acceptance test cases since it is costly. An important conclusion of their study is that a company may have to prioritize which manual test cases to be automated.

As stated by Hushalini et al (2014) if a company is having their testing process formalized, automating some repetitive, but necessary testing tasks is advantageous. Further, it helps to improve the coverage of testing also by including additional testing scope that will be difficult to perform with manual testing.

Even though test automation is mostly done in the test execution phase, it is possible to do it in any phase of the testing process such as test case designing, defect reporting. (Garousi & Elberzhager, 2017)

Garousi and Zhi, 2013 (as cited by Garousi & Elberzhager, 2017) have revealed that most of the test engineers in many companies consider only the test case execution tools such as "record and play-back" tools, when the term "Software Test Automation" comes into picture. Most of these engineers are unaware that automation is possible throughout the software development life cycle as well as in different test activities within the software testing life cycle.

As cited by Garousi & Elberzhager, 2017, Ammann and Offutt (2008) have modeled how test automation can be applied into each stage in the software testing life cycle which include "Test Case Designing", "Test Scripting", "Test Execution", "Test Evaluation", "Reporting Test Results" and also "Test Management" and other activities related to QA engineering. It is illustrated in Figure 2.1 below.

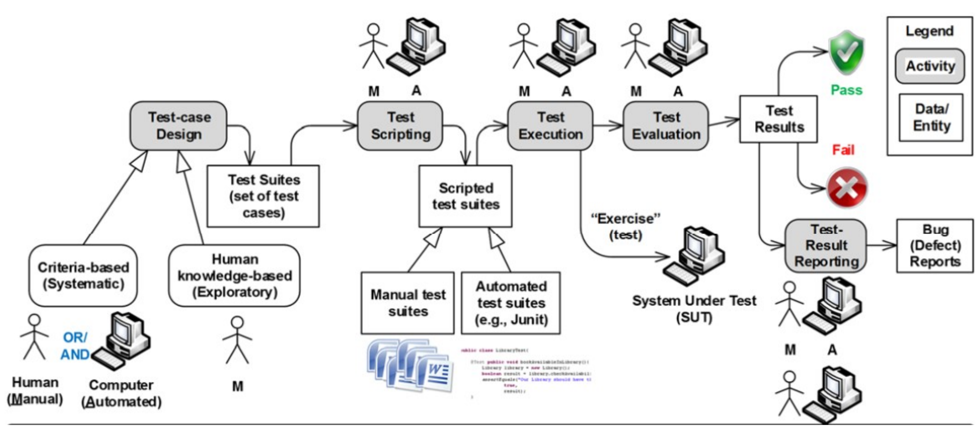

Figure 2.1: Applying test automation into Software Testing Life-cycle

Further, Garousi & Elberzhager, 2017 have mentioned that each of these activities can be done as “fully manual” where automation is not there at all, “partially automated” where some part is done manually while others are automated and “fully automated” where all the activities are automated with some tools and techniques. The authors have done a survey in a company who applies automation in test planning and test case designing and found that there is a 341% Return on Investment (ROI) with zero compromise of test effectiveness due to the automation.

Fewster and Graham (1999) (as cited by Wiklund K. et al.) have revealed that the stability and the structure of the testing process have an impact on the success of test automation. Tight schedule and deadline pressure are the main reasons for process deviations, and it is a high probable situation in the IT industry. Therefore, failure rate of test automation initiatives due to process deviations are considerably high. Further, test automation is considered as an obstacle by its users and therefore, there is a risk that some testing will be ignored by its users.

Wiklund K. et al have come up with a model which depicts how different factors are affecting the success or failure of test automation. As per their model represented in figure 2.2, process deviation is categorized under ‘Behavioral Effects’.

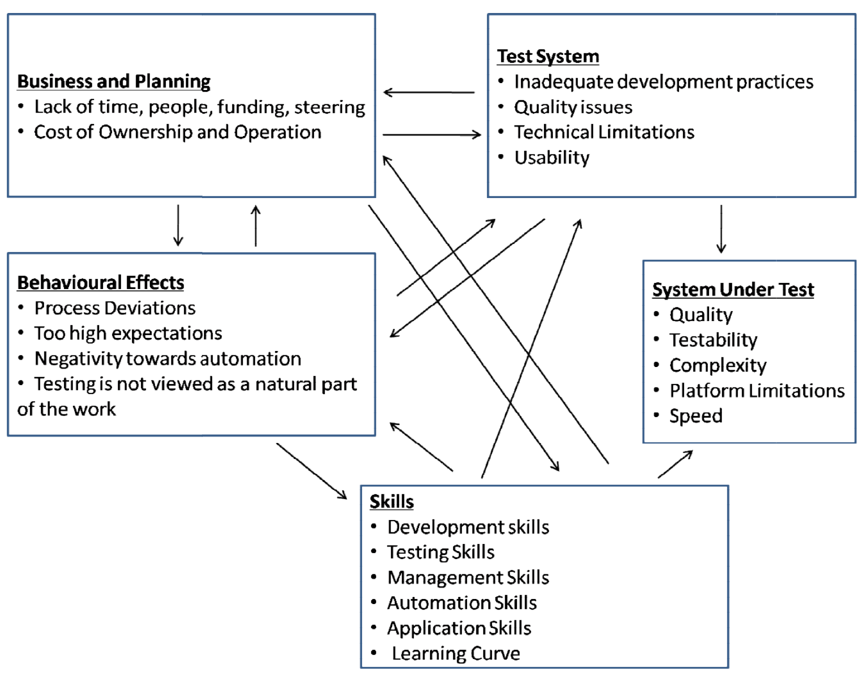

Figure 2.2: Factors Affecting Automation Success or Failure

Taipale, Kasurinen and Smolander (2010) have pointed out that a successful test automation initiative has the ability to reduce the cost and improve the quality of a software and also to improve the software testing process. As cited by Kasurinen, Taipale and Smolander (2010), ISO 29119, a software testing standard also focuses on improving the software testing processes while having an objective to have a company level model for the testing processes.

2.4. Transitioning from Manual Testing to Test Automation

Even though research studies suggest different techniques for test automation, the complexity of those techniques and the challenges faced by practitioners are not being considered much. There is a risk when applying such techniques into practice. When considering the research studies those are smaller in size and therefore, it is not possible to evaluate some longer-term effects, for example refactoring and test scripts maintenance.(Alegroth, Feldt, & Olsson, 2013) However, Kumar and Mishra (2016) also have mentioned that timely maintenance of automated test suites is essential even though it is being a major drawback in test automation due to the high cost.

As stated by Kumar and Mishra (2016) a lot of factors to be considered when adapting test automation in a software project. Which feature requires automated testing, will test automation be with in-house scripting or outsourcing, any commercial tools to be purchased, required level of training are some of those factors. Further, test automation requires high investment initially due to several reasons such as the required feature analysis, scripting, tool procurement and training. Mostly the industrial software is released out in versions where the software is growing regularly with additional functionality added in each version. In such cases a right amount of test automation is necessary for existing functionality and it influences on the time saving and cost effectiveness. (Kumar & Mishra, 2016). Another benefit of test automation is that it allows expert testers to be utilized for some other complex testing tasks without them being engaged with monotonous regression test executions repeatedly.

Alegroth, Feldt and Olsson, 2013 have stated that transitioning large manual test suites to automated suites could be costly. Therefore, a proper cost-benefit prioritization model should be developed and used in order to identify which test suites are beneficial to be automated.

Further, when transitioning from manual testing to test automation, manual testing costs increase linearly with each script development iteration, because script needs to be validated by comparison with manual testing. However, automation script development has a high cost at the initial stage only and later the execution cost is constant. Return on Investment (ROI) can be achieved in this approach with the repetitive execution of automated tests with a greater frequency.

Another drawback of automated test scripts is that the test scripts themselves can be faulty especially when the scripts are complex. Therefore, it requires a comparison with the outcome of manual tests.

Rooksby et al. (2009) (as cited by Wiklund et al.) has pointed out that the introducing test automation to a company needs to be done carefully because it also can be considered as an organization change and therefore, there is a high probability that the resistance to change can be happened from any layer in the company including the top management to the manual test engineers. This will lead to the lack of management support for the automation and the lack of motivation of test engineers due to the fear of job loss.

2.5. Impact of test automation on cost and quality of software

Even though the software testing is time consuming and it has a resource-hungry nature, it is not possible to ignore the testing. As mentioned by Kumar & Mishra (2016) 40% to 50% out of overall resources, 30% out of overall effort and 50% to 60% out of the overall cost are required for testing in software projects while the testing is being the major challenge in software development. Automated testing replaces the laborious and time-consuming manual testing. Further, it facilitates formal coverage of tests, avoid human errors, and expedite the process of test execution which is being the most effective solution for meeting the strict timelines. (Kumar & Mishra, 2016)

As per the case study done by Leotta, Clerissi, Ricca, & Tonella (2013), transitioning from manual testing to GUI test automation had a large gain in terms of improved quality, development cost and development time because, a large set of test cases can be executed more rapidly and at a higher regularity. This repetitive testing was also important for this particular case study since the system could be tested only with the manual testing and there were no other tests such as automated unit tests in order to cover up the regression testing.

According to Amannejad et al (as cited in Garousi & Elberzhager, 2017) even though automation testing gives several benefits over manual testing such as ability to execute the tests repeatedly and reducing cost and manual effort, those benefits cannot be obtained if the automation is not planned properly and implementation was not done properly. It will lead to an additional cost and effort and detecting defects will also be less effective. Further, Garousi and Elberzhager (2017) are emphasizing that automation is not available freely even though there is a large amount of test automation tools available in the industry. Therefore, in order to be benefitted from automation, the companies have to make right decisions on tool selection considering the adequate level of automation, which phases of the QA process to be automated, which tools can be used considering their cost and technical knowledge available within the company.

Saher, Khan, Shahzad and Karim (2015) also have pointed out that automation testing is more costly compared to the manual testing. It needs a considerable initial investment. However, when it comes to regression testing where the same tests are executed repeatedly, cost of test execution is relatively low when comparing with the cost of repeated testing cycles done manually. As cited by the author, Bach (1999) has pointed out, manual testing and automated testing cannot be compared in terms of their costs because those are two different processes and are not two different methods to execute the same process. Further, he is highlighting that the bugs identified with these two processes are also different.

In the study of Saher, Khan, Shahzad and Karim (2015), they have considered cost, time and number of bugs detected during functional, security and performance testing in the automated testing and manual testing. They have found that automation cost is higher than manual testing cost when considering the licensing cost for the tools, salary, training cost and maintenance cost. However, they have revealed that automation testing time is around 50% of the manual testing time. Further, defect detection capability is also high in automation testing compared to the manual testing. As per the study results, automation testing is capable of identifying 70-80% of functional issues while it is around 60-80% in manual testing.

2.6. Capture-replay vs programmable test automation

Accommodating the required level of quality in software is challenging due to the quickly evolving nature of web applications. There are numerous approaches for testing web applications and selecting an approach depends on several factors such as the web application development technology and tools used for testing the web application. (Leotta, Clerissi, Ricca, & Tonella, 2013). Leotta et al. has identified 2 main approaches as “Capture and Replay Web Testing” (C&R) and “Programmable Web Testing” along with benefits and limitations of both approaches. C&R approach records the testers’ actions which are performed in the web application, and generates a script automatically, to be used for re-execution whereas programmable web testing requires non-trivial skills in programming and the effort involved with it is comparable to the effort required for the web application development. However, reusability of common functions, conditional execution, and accurate mechanisms to place the elements and widgets available in the user interface are some of the benefits in programmable web testing. (Leotta, Clerissi, Ricca, & Tonella, 2013)

As per the authors even though the “Capture & Replay” approach can be used to verify the correctness of interactive applications, it is quite fragile because a minor change in the user interface requires alterations in previously recorded test cases due to the fact that it hard codes the values in the scripts. Further, C&R test cases are inexpensive to write but expensive to maintain with the evolution of software. Selenium IDE is one of the tools using the C & R approach which is considered by Leotta et al in their study. It allows testers recording, editing and debugging test cases written in Selenese scripting language and it supports smart UI element selection. (Alegroth E, Feldt R, & Olsson, 2013)

The test scripts being written in the programmable web testing approach are more flexible and easier to handle than the scripts built with C & R approach. It has the capability of handling the complexity of the web application due to the capability of handling conditional statements. However, scripting with a programmable web testing approach requires a remarkable initial effort as well as it will be costly because programming guidelines and best practices that are applied to traditional software development are applicable here also. Leotta et al. have considered Selenium WebDriver as a programmable testing tool in their study. This tool uses the page object model as a best practice. When the web application evolves, testers have to update the test cases accordingly and it requires a considerable effort.

Capture & replay techniques which are used to automate system-level tests has another drawback of being fragile if the software under test is frequently being changed in its Graphical user Interface (GUI) and APIs. (Leotta et al., 2013)

Different capture & replay tools are using different techniques to interact with the GUI such as using widget level identifications, using coordinates. However, both these approaches have limitations since there is a possibility that some changes can happen in GUI layout, code structure or API level since the software is under development. (Leotta et al., 2013)

As per a case study done by Leotta et al. (2013), even though some tools are out there to facilitate capture and replay test automation technique, some of them have limitations such as high investment cost, inability to interact with the UI map, limitation of not having built-in support to develop and maintain test suites, limitations related with scripting language because, some testers who supposed to write or modify the auto-generated scripts are not familiar with some of the programming languages.

A main advantage of automated testing which uses record and play-back technique is the repeatability as well as its extensibility to perform testing tasks impossible with manual testing. (Hushalini, Randunu, Maddumahewa, & Manawadu, 2014)

The test scripts generated via capture and replay tools are not solid as the automation scripts that are written by programing. (Wiklund, Eldh., Sundmark & Lundqvist, 2017). This will introduce a risk of rework. However, programming automation scripts require high technical skills and therefore, test automation should be considered and treated as software development. When the automation engineers have the software development knowledge and skills, they can do automation scripting efficiently and effectively which result in a successful test automation.

2.7. Test automation in IT industry in Sri Lanka

As per a study done by Hushalini et al., 2014, even though most of the IT companies in Sri Lanka are following faster and efficient methodologies in their software development process such as Agile - SCRUM, Agile - XP etc. most of them do not use automation tools for testing. Therefore, efficiency, repeatability and faster defect identifications are at average level. (Hushalini et al., 2014)

This study has revealed that automation testing does not fully replace manual testing since test automation needs more technical human resources who should be capable of handling testing tools and also the cost for the automation testing is higher than the manual testing cost.

As per a study done by Hushalini et al., 2014, 45% of IT companies in Sri Lanka are using some white-box testing approaches also in their software testing process. Therefore, they do not use test automation tools. However, the majority of the sample selected in this study agrees that automated testing enhances the quality of the software product due to the greater test coverage.

As in Figure 2.3 and 2.4, lack of skilled resources and lack of management understanding are the major challenges which affect test automation in the IT industry in Sri Lanka. Regular requirement changes, cost, immaturity of automation testing frameworks and lack of coding standards and best practices are also some other challenges people have to face when implementing test automations. (Hushalini, Randunu, Maddumahewa, & Manawadu, 2014)

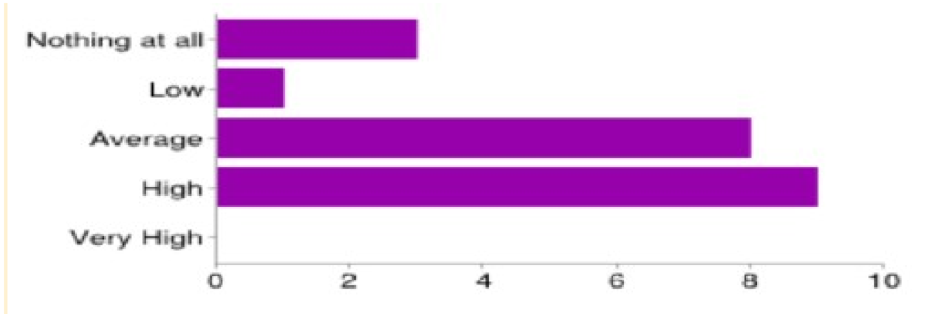

Figure 2.3: Lack of Skilled Resources

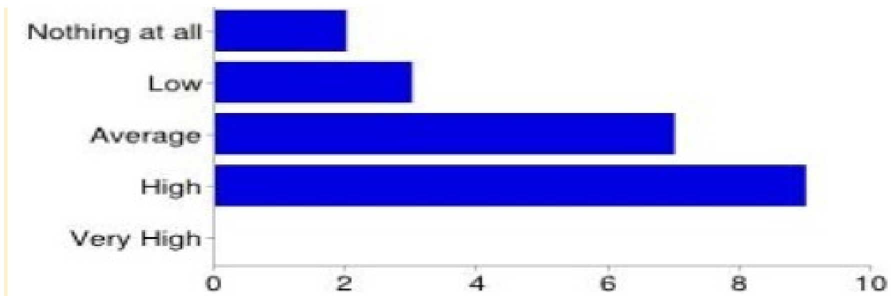

Figure 2.4: Lack of Management Understanding

However, this study has revealed that the companies who are using test automation gain benefits such as efficiency, faster and earlier defect identification, increase in confidence, increase in satisfaction of the testers and increase in test coverage.

3. RESEARCH METHODOLOGY

3.1. Introduction

This chapter discusses the "Research Problem" and the "Methodology" used to conduct this research in order to achieve the research objectives which are discussed in Chapter 1.

Research problem is described briefly in Section 3.2. Research Methodology is discussed in Section 3.3. Information regarding the population and the sample selection for this study are discussed in Section 3.7 while the data collection process is described in Section 3.8.

3.2. Research Problem

Software Testing Life-cycle Methodology (STLM) is a systematic approach to be followed in SQA when doing the functional testing manually (Dubey, Takwane, & Dighe, 2017) while ATLM is being a systematic approach for automated testing (Dustin, Paul and Rashka, 2001).

However, such a systematic approach or a process for test automation is rarely discussed in the literature even though a considerable number of studies have been conducted in the SQA field focusing on test automation. Especially when it comes to the QA domain in the IT industry in Sri Lanka, only a limited number of research studies have been conducted with regards to test automation.

Therefore, since there is a research gap in this area, this study is focusing on identifying whether following ATLM is having an impact on the success of test automation in the IT industry in Sri Lanka.

3.3. Research Method

The Research methodology followed in this research is depicted in figure 3.1. A comprehensive literature review was carried out focusing on the software test automation domain and it led to identify the research gap as described above under the topic "Research Problem". This study intends to analyze whether following ATLM is having an impact on the success of test automation.

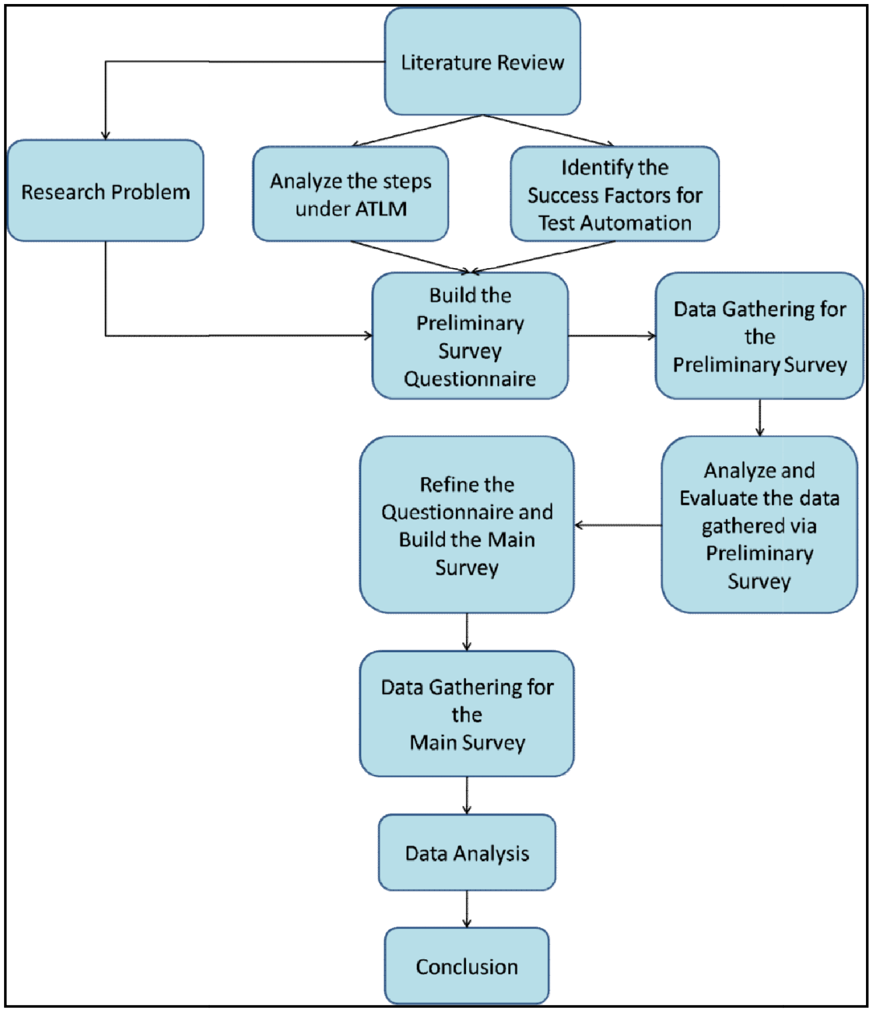

Figure 3.1: Research Methodology

This study was conducted as a quantitative research with a structured questionnaire due to several reasons. As the population of this study is in the IT field, they are familiar with online surveys and therefore, no orientation is needed on the survey submission. Since this study is based on a theoretical concept called ATLM, it is more focused and used to do some sort of verification on that theory. Further, the sample applicable for this study is relatively large. The objectives of this study could be achieved with analytical methods considering some statistical data. Considering these facts, quantitative research methodology is more suitable for this study than qualitative research methodology.

3.4. Conceptual Framework

Figure 3.2 depicts the conceptual framework of this study which is built upon finalizing the research problem after a comprehensive literature review. Since the intention of this study is to identify the impact of following ATLM on success of test automation, the 6 stages in ATLM which are used to derive whether ATLM is followed or not, are the Independent Variables (IVs). Therefore, "Decision to Automate Tests", "Test Tool Acquisition", "Automated Testing Introduction Process", "Test Planning, Design & Development", "Execution & Management of Tests", "Test Program Review & Assessment" are the IVs. The level of success in test automation is the Dependent Variable (DV) in this study.

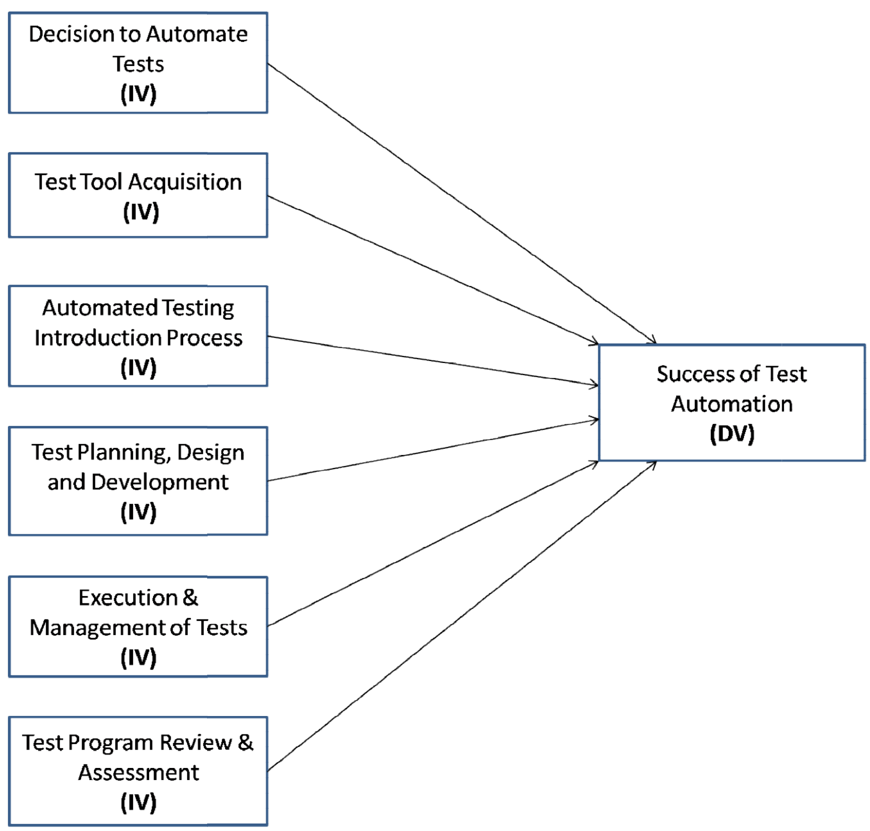

Figure 3.2: Conceptual Framework

3.5. Development of Hypotheses

Following are the hypotheses developed based on the above conceptual framework presented at Figure 3.2. They are categorized under each IV.

Decision to Automate Tests

$H1_a$ **-** Decision to automate tests has an impact on the success level of test automation.

$H1_0$ **-** Decision to automate tests does not have an impact on the success level of test automation.

Test Tool Acquisition

$H2_a$ **-** Test tool acquisition has an impact on the success level of test automation.

$H2_0$ **-** Test tool acquisition does not have an impact on the success level of test automation.

Automated Testing Introduction Process

$H3_a$ **-** Automated testing introduction process has an impact on the success level of test automation.

$H3_0$ **-** Automated testing introduction process does not have an impact on the success level of test automation.

Test Planning, Design and Development

$H4_a$ **-** Test planning, design and development have an impact on the success level of test automation.

$H4_0$ **-** Test planning, design and development does not have an impact on the success level of test automation.

Execution and Management of Tests

$H5_a$ **-** Execution and Management of tests have an impact on the success level of test automation.

$H5_0$ **-** Execution and Management of tests does not have an impact on the success level of test automation.

Test Program Review & Assessment

$H6_a$ **-** Test program review and assessment have an impact on the success level of test automation.

$H6_0$ **-** Test program review and assessment does not have an impact on the success level of test automation.

3.6. Questionnaire Design

As per the conceptual framework and hypothesis described in the previous topics, the questionnaire was designed with the aim of deriving the information whether the ATLM is followed and the level of success in test automation.

The fact that ATLM is followed or not, is derived by determining how each step in the ATLM is followed during the test automation procedure. All the questions related to IVs, in the other words related to the steps in ATLM are derived by considering the detailed content of each step in ATLM as described by Dustin et al. (1999)

Table 3.1 describes how the questions in the survey are mapped in order to determine whether each step in the ATLM is followed or not. The column "Description/Content" includes the summary of each step in the ATLM in high level.

Each of these questions is added in the survey questionnaire with a 5-point Likert scale.

Table 3.1: Survey Question Mapping for IVs

Steps in ATLM	**Description/Content**	**Questions in the Survey (Answer type: 5-point Likert scale (Never, Rarely, Sometimes, Often, Always)**
Variable: IV1 **No. of Questions in the Survey:** 9		
Decision to Automate	• Manage Expectations ○ Outline potential	Q4. What are the things that QA/automation team will do when

Tests	benefits & test tool proposal • Overcome false expectations for automated testing (management may expect to get automatic test plans, replace human factor etc) • Benefits of automation o Reliability o Quality o Schedule • Acquiring management support o Influence management to use automation o Plan and do trainings and inform management o Point out the importance of purchasing a tool & allocating human resources o Keep them informed about the costs o Keep them informed about the issues faced when adapting a new tool	deciding to automate the testing in a particular project? (i) Takes the initiative and influence the management to use automation in projects. (ii) Gets the clear understanding about the capabilities of the automation tool/framework. (iii) Gets the clear understanding about the required level of technical expertise. (iv) Prepare a project proposal for the test automation project. Q5. In the cost-benefit analysis being done before starting the test automation in a project; (i) Quantitative benefits (eg: reduction in cost & schedule etc) are assessed. (ii) Qualitative benefits (eg: system reliability and confidence level etc) are assessed. (iii) Cost factors (eg: cost for the tool purchasing, training costs, initial schedule increase etc) are considered. Q6. What are the things being communicated to the top management in order to get their support for the test automation; (i) Required skills/capabilities of the testing team and the training requirements. (ii) Costs incurred such as initial tool purchasing, schedule increase and training costs.
Variable: IV2		

No. of Questions in the Survey: 4		

Test Tool Acquisition	• Tool evaluation and selection process
	  ○ Confirm management support
	  ○ Create a tool evaluation criteria
		Q7. When selecting a test tool/framework;
		
		(i) Both Commercial & Free tools are considered.
		(ii) A set of evaluation criteria is used to evaluate the tools.
		(iii) Different capabilities of automation tool/framework are considered.
		(iv) Issues/limitations of automation tool/framework are considered.

Variable: IV3 **No. of Questions in the Survey:** 6		

Automated Testing Introduction Process	• Test process analysis
	  ○ There should be an overall test process and a strategy, goals and objectives
	  ○ Test process should be documented and communicated to the team
	  ○ Early test team participation is emphasized
	• Test tool consideration
	  ○ Project's requirements should be considered before getting a tool
	  ○ Tools should be mapped to testing requirements
	  ○ Test tool compatibility with the application and the environment should be considered
		Q8. Regarding the test process of the company;
		
		(i) A standard process/procedure is followed in the manual testing.
		(ii) The test process is documented and communicated to the test team.
		(iii) The test process of the company is being considered when applying test automation into projects.
		
		Q9. When choosing a test automation tool for a particular project;
		
		(i) Investigate whether an existing tool could be used for the new project.
		(ii) Consider the testing requirements of the project.
		(iii) Consider the test tool compatibility with the testing environment.

Variable: IV4		

No. of Questions in the Survey: 10		

Test Planning, Design & Development	• Test Planning
	  o Test procedure creation standards and guidelines
	  o Test data and test schedule
	  o Hardware, software, network
	  o Defect tracking procedure
	  o Roles and responsibilities
	  o Risks and contingencies
	  o Acceptable level of thoroughness
	• Test Design
	  o Number of tests to be performed
	  o Ways that tests will be approached
	  o Test conditions
	  o Test design standards
	  o Test requirements and procedures
	• Test Development
	  o Reusability, maintainability, repeatability
	  o Test development standards
	  o Test development procedures
		Q10. What are the factors considered when planning to automate tests after finalizing a tool/framework?
		
		(i) Hardware, software and infrastructure.
		(ii) Test data.
		(iii) Test schedule
		(iv) Roles & responsibilities for team members.
		(v) Risks & contingencies.
		
		Q11. What are the factors considered when designing & developing test cases for automation?
		
		(i) Thoroughness of the scope to be automated.
		(ii) Logical grouping of test cases (eg: grouping test cases based on the modules in the system, consider the order of test execution etc).
		(iii) Reusability - extending some existing test cases.
		(iv) Repeatability - executing the same tests repeatedly.
		(v) Maintainability.

Variable: IV5 **No. of Questions in the Survey:** 4		
Execution & Management of Tests	• Schedule compliance • Executing plans for unit, integration, system and user acceptance testing • Documenting test results • Test outcome evaluation • Test metrics for test coverage, progress and the quality of the test effort	Q12. When Executing the automated test cases; (i) Automation is executed within the planned timeline of overall test execution. (ii) Automated test cases can be executed in different levels such as unit, integration, system and user

		acceptance tests. (iii) Failed test cases are manually verified (to confirm whether they are valid bugs). (iv) A report with test results will be created by the automation tool itself or manually.
Variable: IV6 **No. of Questions in the Survey:** 3		
Test Program Review & Assessment	• Need to conduct the reviews throughout the life-cycle • Final review and assessments to identify the process improvements • Review the performance • Tracking lessons learned • Assess the effectiveness to identify the ROI	Q13. After the test cases are implemented and executed; (i) Effectiveness of test automation is assessed and Return on Investment (ROI) is evaluated. (ii) Performance of the test automation process is evaluated (considering the time taken to automate the given test scope) (iii) Lessons learned activities are tracked and considered for improvements in the future

Several past research studies have come up with some models to assess the success of test automation in terms of cost, schedule and effectiveness (Amannejad, Garousi, Irving & Saha, 2014; Jayachandran, 2005). However, it is not practical to assess the test automation success with such a model under this study because it will lead to a wide scope and cannot be absorbed under this study. Therefore, in this research study the success of test automation is represented as a "level" of test automation success which can be presented in a numeric score and can be considered as a relative measurement rather than considering an absolute number to measure the automation success quantitatively. Further, the level of test automation success is measured by considering 8 Critical Success Factors(CSFs) suggested by Rodrigues and Dias-Neto (2016) and another 3 CSFs suggested by Merrill (2020) in addition to the earlier mentioned 8 CSFs. However, as per the literature review several scholars have identified different CSFs and all of them can be mapped with these 11 CSFs. Considering this fact and also the scope of this research, these 11 CSFs are considered to measure the level of success in test automation within this research study as mentioned in Table 3.2. It includes how the respective questions in the survey are mapped to each CSF.

Table 3.2: Survey Question Mapping for DV considering CSFs of Test Automation

Variable	**Factors for Test Automation Success**	**No. of Questions**	**Questions in the Survey (Answer type: 5-point Likert scale (Never, Rarely, Sometimes, Often, Always)**
DV: Level of Test Automation Success	(i) Automation Planning (ii) Feasibility Assessment (iii) Dedicated & Skilled team (iv) Resource Availability (v) Scalability	11	Q14. Select the correct answer regarding the test automation implementation and execution (i) Automation is well planned considering goals, Return on Investment (ROI) and resource requirements. (ii) A feasibility analysis is done before applying test automation into a project (considering technical & economic feasibility). (iii) Dedicated & skilled people are available for test automation. (iv) Test tool/test environment is available when needed. (v) Resources (hardware & personnel) are available to work on multiple automation projects simultaneously.
	(i) Maintainability (ii) Resource Availability (iii) Well defined		Q15. In automation scripting; (i) Software development best practices are used.

	test process		(ii) Test scripts are re-used for similar test requirements. (iii) Automated test cases are developed before, or in parallel with, application development.
	(i) Multiple environment support (ii) Repeatability (iii) Reliability		Q16. When executing the automated tests; (i) Automated tests are executed in multiple environments. (ii) Automation is setup to be executed automatically on a defined frequency (eg: daily). (iii) Test results are same when executing the same tests multiple times.

3.7. Population and Sample Selection

The details of the population and the sample selection are described in section 3.7.1 and section 3.7.2 respectively.

3.7.1. Population

The population applicable for this study is the Software Quality Assurance professionals in the IT industry in Sri Lanka. According to the National IT - Business Process Management(BPM) Workforce Survey conducted by Information and Communication Technology Agency(ICTA) of Sri Lanka in 2019, total ICT workforce in ICT organizations in Sri Lanka is 81,741 in the year of 2018 (SLICTA 2019). Out of this, 17.25% are SQA professionals (SLICTA, 2019). Therefore, the population of this research study, the number of SQA professionals in IT organizations in Sri Lanka, is 14, 100.

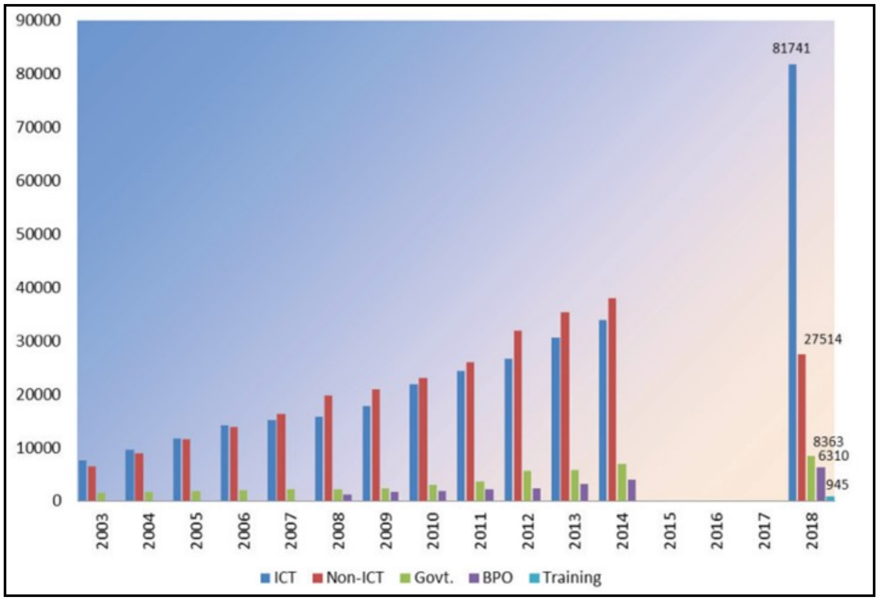

Figure 3.3: ICT Workforce by Major Employer Categories

Source: SLICTA (2019)

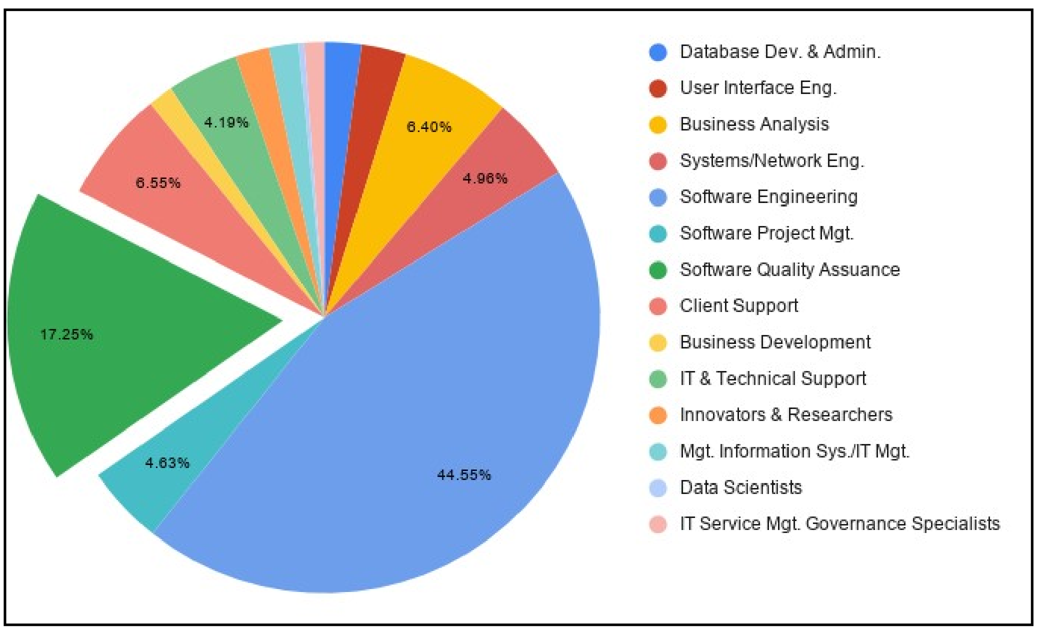

Figure 3.4: Composition of Workforce in IT Organizations - based on Job Category

Source: SLICTA (2019)

3.7.2. Sample

The sample size for this study is calculated by taking the population size as 14,100 and considering the Confidence level as 95% and Margin of Error as 5%. Therefore, the sample size for this study is 374. (Qualtrics, 2020)

Voluntary Response Sampling technique is used for this study as it is convenient to distribute the online survey questionnaire among QA professionals through the colleagues who are working in IT organizations as well as some social media groups. Then those who are willing to submit the survey have voluntarily submitted it. (Taherdoost, 2016)

3.8. Process of Data Collection

The survey questionnaire was made available online by creating it using Google forms. It was shared among QA professionals by directly sharing with known QA professionals, making it available for QA professionals by sharing via others who are working in other job categories, sharing in several social media groups including LinkedIn, Facebook and WhatsApp.

Data collection was done in 2 stages; as a pilot survey and the main survey. After the questionnaire was created initially, it was shared with some known QA professionals and their responses were taken for the pilot survey. The details of the pilot study are described under the topic 3.8.1. Pilot Survey.

Survey questionnaire was finalized by doing some refinements to the initial questionnaire, based on the pilot study analysis. Once the main questionnaire was finalized it was shared among QA professionals in order to collect the data for the main survey.

3.8.1. Pilot Survey

Initial questionnaire was reviewed by two QA professionals who are working as QA leads. One of them is having around 5 years of experience with test automation and the other one is having Statistics background which helped to get some feedback on the questionnaire considering the test automation domain perspective as well as the quantitative survey data analysis perspective. Based on their feedback, the questionnaire got improved by rewording some of the questions and changing the answer type for some of the questions. Initial questionnaire had few questions with Yes/No answer type but they got updated into 5-point Likert scale questions.

The updated questionnaire was shared among 15 known QA professionals who are working in multiple organizations and at different levels in their job roles such as QA Engineer, Senior QA Engineer & QA Lead in order to obtain highly reliable responses. These 15 responses were taken for the pilot study.

3.8.1.1. Reliability Analysis of the Pilot Survey

Since the questionnaire consists of several questions to measure each IV & DV, it is vital to measure the internal consistency of the questions related to each variable. This was achieved through calculating Cronbach's Alpha for each IV & DV with the pilot study. Cronbach's Alpha is a value which could be ranging from 0 to 1 and as the rule of thumb, 0.7 and above is the acceptable range. (Tavakol and Dennick, 2011)

However, as per the data analysis in pilot study, Cronbach's Alpha was 0.5832 for one of the IVs which is below the acceptable range.. Therefore, the questions related to that IV were reviewed and 2 questions were combined in order to improve the inter-relatedness. Then this revised questionnaire was given for another 15 QA professionals and Cronbach's Alpha value was calculated with the collected data. Those values were in the acceptable range as in the Table 3.3.

Table 3.3: Cronbach's Alpha

Variable	**No. of Questions**	**Cronbach's Alpha Value**
IV1: Decision to automate tests	9	0.7852
IV2: Test tool acquisition	4	0.7498
IV3: Automated Testing Introduction Process	6	0.7238

IV4: Test Planning, Design & Development	10	0.8858
IV5: Execution & Management of Tests	4	0.8899
IV6: Test Program Review & Assessment	3	0.8400
DV: Success level of test automation	11	0.8584

Since the Cronbach's alpha values were in the acceptable range no more changes were done to the questionnaire and it is shared with the QA community in order to collect the data for the main survey.

3.8.2. Main Survey

Once the questionnaire was finalized after updating some of the questions based on pilot study, it was shared with the QA community in Sri Lanka. An email flyer was shared among IT professionals requesting to share it with the QA teams in their organizations. Some personalized emails also sent to the known contacts. Further, it was posted in a social media group of QA professionals in Sri Lanka which includes 25,000+ QA professionals.

100+ responses were received resulting in a 26% response rate after around 10 days from the date when the questionnaire was published initially. However, response rate was slowing down, and it seemed to be difficult to get the required number of responses. Then reminders were sent, and some follow ups were done with the known people in order to get more responses. However, 211 responses were received resulting in a 64% response rate after 2 months from the initial survey publishing date. Therefore, this study is done with 85% of confidence level and 5% of margin of error.

4. DATA ANALYSIS

4.1 Introduction

The process of analyzing the data collected with the online survey is discussed throughout this chapter. A Descriptive Analysis was done with the demographic data and Inferential Statistics analyses were used so as to make generalization for the population based on the data collected with the sample. Mainly the correlation between each IV and DV are analyzed and the results are discussed in this chapter.

4.2 Data Analysis Tools and Techniques

Descriptive analysis and inferential statistics analysis techniques are used in this research study and Expert Judgment was used to interpret some of the results obtained with these analyses. The statistical analyses were done using the IBM SPSS 27 tool.

The descriptive statistics was used to visualize the distribution of the sample. Inferential analysis was done covering Comparison, Correlation and Regression analyses. The Analysis of Variance (ANNOVA) is used to see the comparison of variables. The correlation between each IV and DV was analyzed with Pearson's Product-Moment Correlation while a Multiple Regression was used to analyze the overall relationship between IVs and DV since the IVs of this study collectively discusses a common process called ATLM (Bevans, 2020).

4.3 Data Cleansing and Transformation

Out of the 240 responses received for the survey questionnaire, there were 29 responses stating that they do not use functional test automation in their companies. Therefore, those 29 responses were not considered for the inferential analysis carried out within this study since the ultimate objective of the inferential analysis is to identify the correlation between each IV & DV so that it will be possible to interpret the impact of following ATLM on the success of test automation.

The data transformation process is carried out in order to feed the survey responses into the statistical data analysis software called IBM SPSS 27 which is used in the data analysis in this research study. The survey questionnaire consists of questions with 5-point Likert scale answer type with the options as Never, Rarely, Sometimes, Often, Always. These options were transferred into numerical values as 1, 2, 3, 4, 5 respectively at the data transformation.

Further, there were multiple questions mapped with each IV and DV. Even though the answer of each question is categorical (with 5-point Likert scale), each IV and DV were separately derived as continuous variables by deriving the summation of the answers given for all the questions mapped into each individual variable separately. This transformation is reasonable and justifiable since all the questions mapped for a single variable are asked in the same direction and the same answer scale is used.

As an example, there were 9 questions mapped with 1st IV. Once all the categorical answers(Never, Rarely, Sometimes, Often, Always) were transformed into numerical values (1, 2, 3, 4, 5) the sum of these 9 questions were calculated and that value is considered as the value for the 1st IV which could be ranging from minimum 9 to maximum 45 and therefore, it can be considered as a continuous variable.

Table 4.1 depicts how each variable is derived as a continuous variable with the answers of Likert scale questions.

Table 4.1: Deriving Continuous Variables from Likert Scale Questions

Variable	**No. of questions mapped in the questionnaire**	**Variable Type**	**Minimum Value**	**Maximum Value**
IV1	9	Continuous	9	45
IV2	4	Continuous	4	20
IV3	6	Continuous	6	30
IV4	10	Continuous	10	50
IV5	4	Continuous	4	20
IV6	3	Continuous	3	15
DV	11	Continuous	11	55

4.4 Descriptive Analysis of Demographic Data

The nature and characteristics of the sample selected in this study are elaborated with the below analyses done with the collected demographic data.

4.4.1 Usage of Test Automation

This research study was conducted with a set of data gathered from 240 respondents and 29 of them, which is a 12% as a percentage, have confirmed that test automation is not being used in their companies.

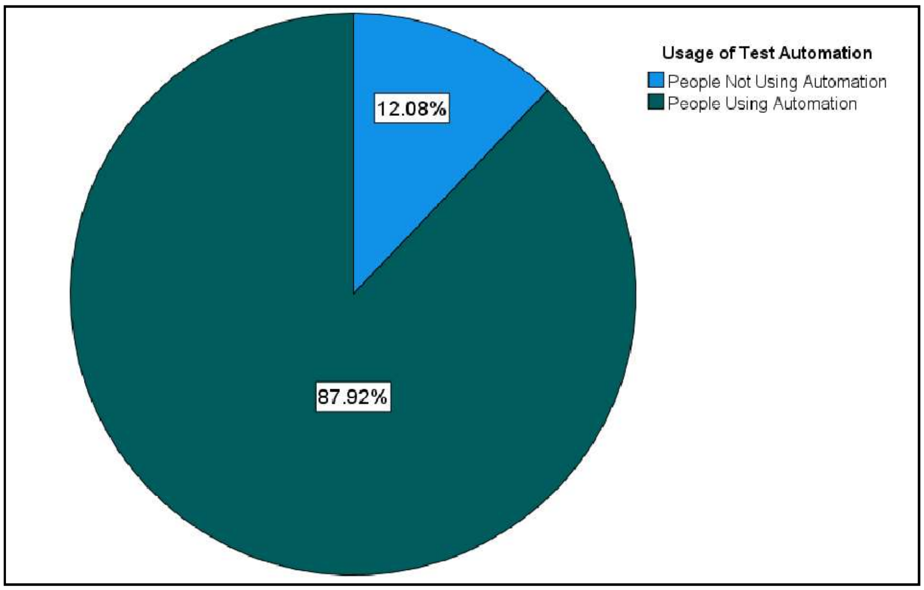

Figure 4.1: Usage of Test Automation

4.4.2 Reasons for not Doing Test Automation

As mentioned above, 29 people have responded as they are not doing test automation at their companies. 5 of them (17%) have mentioned that it is because automation takes more time and cost than manual testing. 17 out of 29 (59%) have mentioned that no one (either QA team or Management) has a requirement or initiative to automate the testing while another 5 people (17%) claimed that they do not have enough management support to take an initiative for test automation. The 2 people (7%) have mentioned that they are not doing test automation since they do not have the required technical expertise.

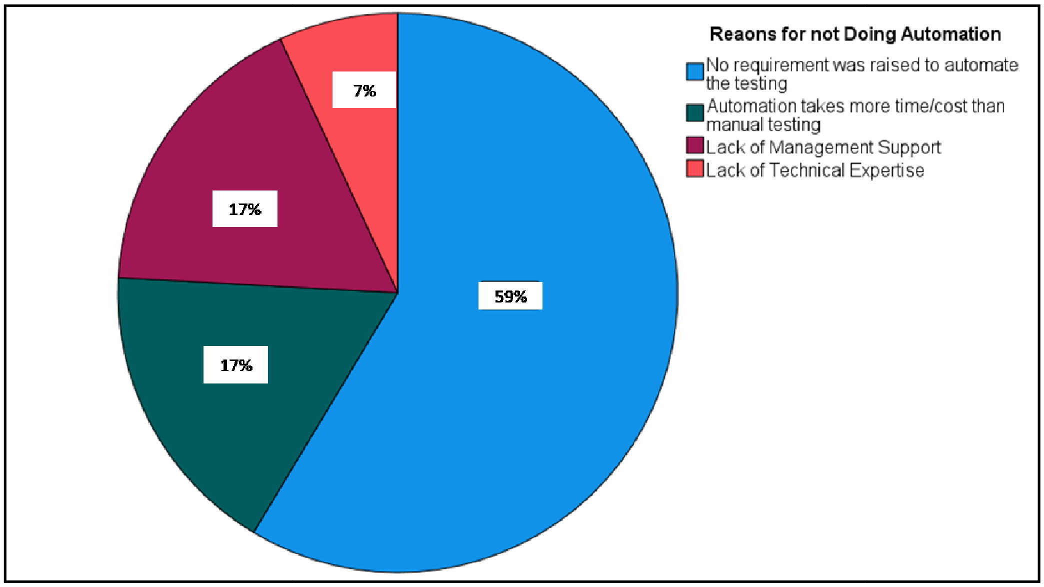

Figure 4.2: Reasons for Not Doing Automation

4.4.3 Distribution of Sample based on Years of Experience

The total number of survey respondents was 240 and majority of them, which is 37.08%, are having less than 3 years of experience in the QA field. 31.67% of the respondents are having 3 to 5 year of experience while 22.92% are having 5 to 10 years of experience in the QA. The people who are having more than 10 years of experience represent 8.33% from the total sample.

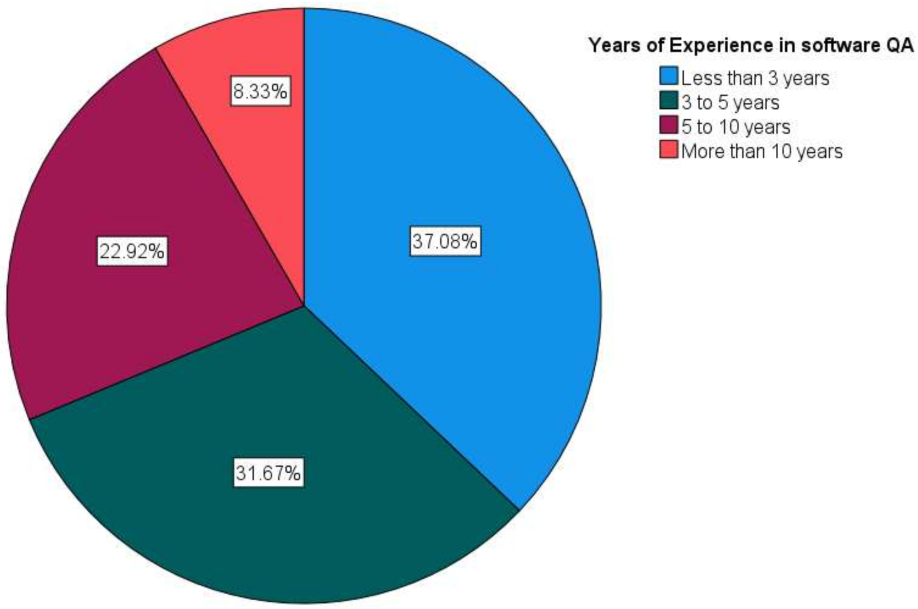

Figure 4.3: Distribution of the Sample based on Years of Experience in QA

4.4.4 Distribution of Sample based on the Category/Level of Job

63.33% out of the 240 total respondents are in the QA Engineer or Senior QA Engineer job category. 8.75% of the sample is Associate QA Engineers or interns of QA.10% of the sample is consisting of Senior/Automation Engineers while 17.92% of the sample is from QA Lead or QA Manager level.

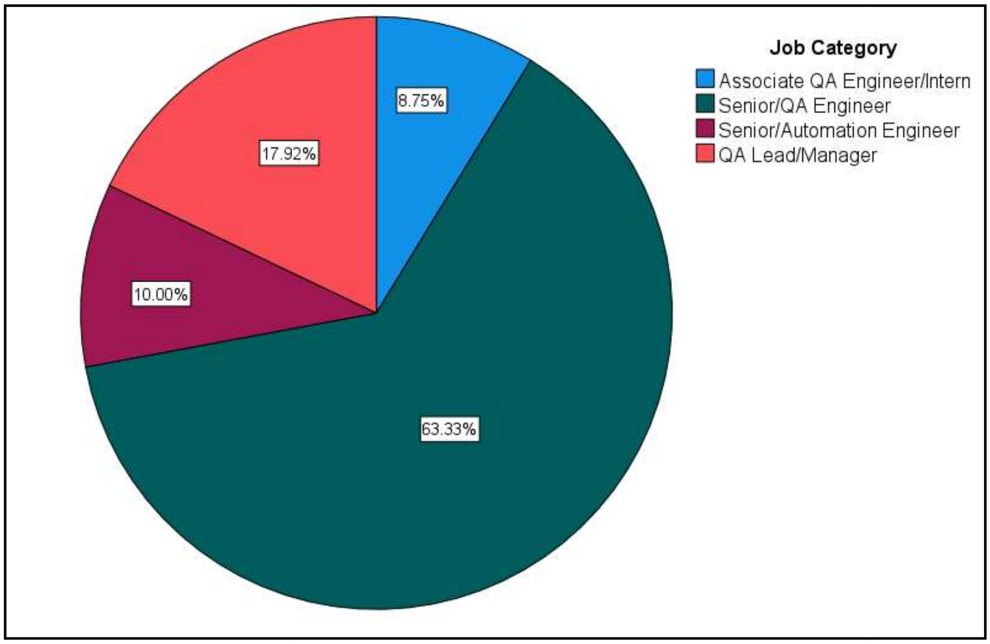

Figure 4.4: Sample Distribution based on Job Category

4.4.5 Distribution of Collected Data for Variables

IV1: Decision to Automate Tests

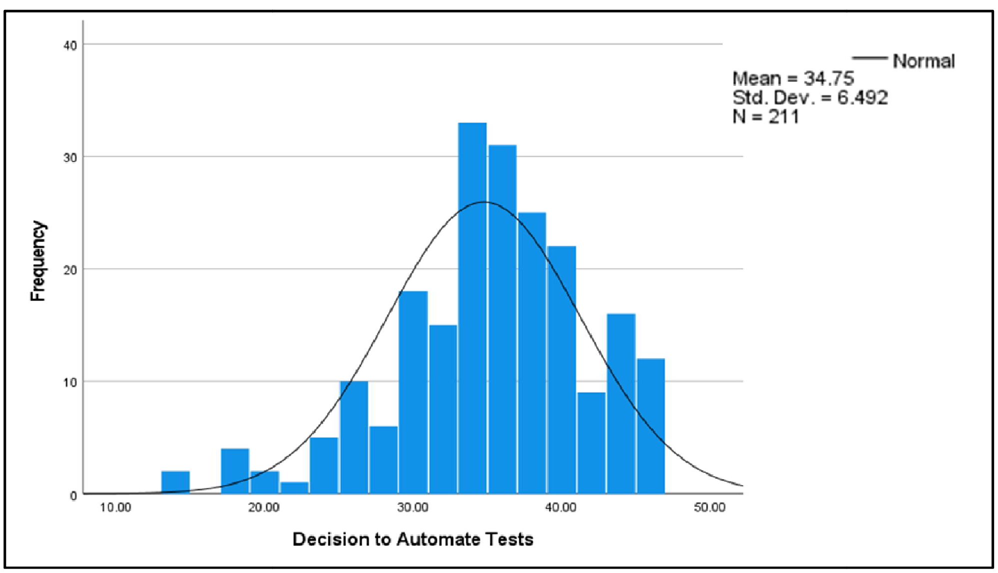

Figure 4.5: Histogram of the data in IV1 (Decision to Automate Tests)

The histogram presented in Figure 4.5 is systematic and therefore, it is possible to conclude that the responses received regarding the Decision to Automate Tests are equally distributed.

IV2: Test Tool Acquisition

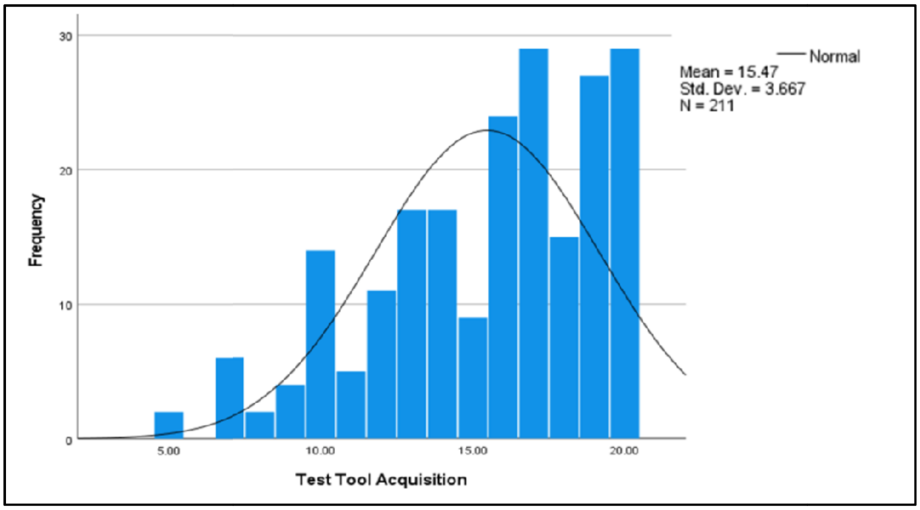

Figure 4.6: Histogram of the data in IV2 (Test Tool Acquisition)

The responses received for the questions related to Test Tool Acquisition are normally distributed as it is depicted in the systematic histogram shown in Figure 4.6.

IV3: Automation Testing Introduction Process

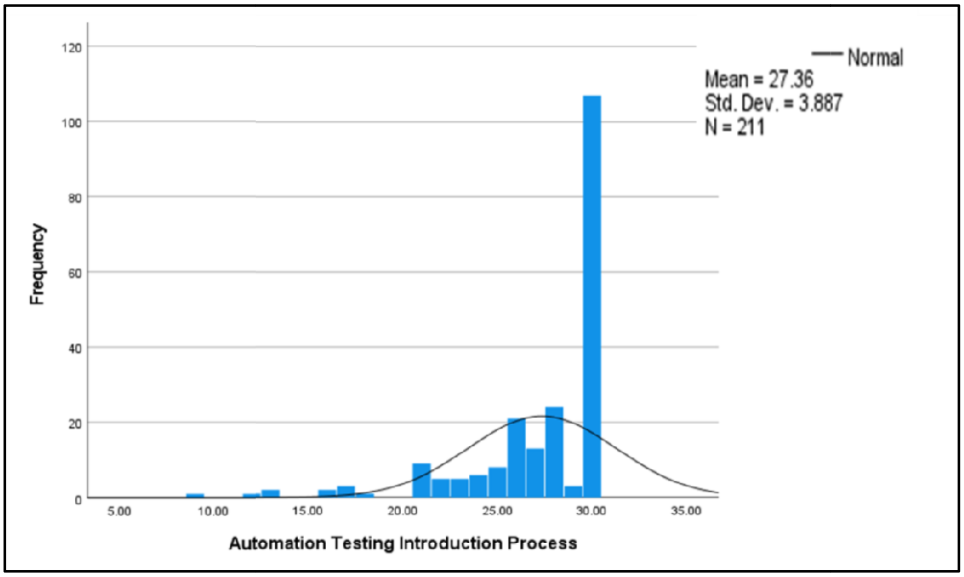

Figure 4.7: Histogram of the data in IV3 (Automation Testing Introduction Process)

The histogram presented in Figure 4.7 is negatively skewed. The majority of the respondents (107 out of 240) have given the ratings for the questions under this IV in a way that the total rating for all the questions is being 30.

IV4: Test Planning, Design and Development

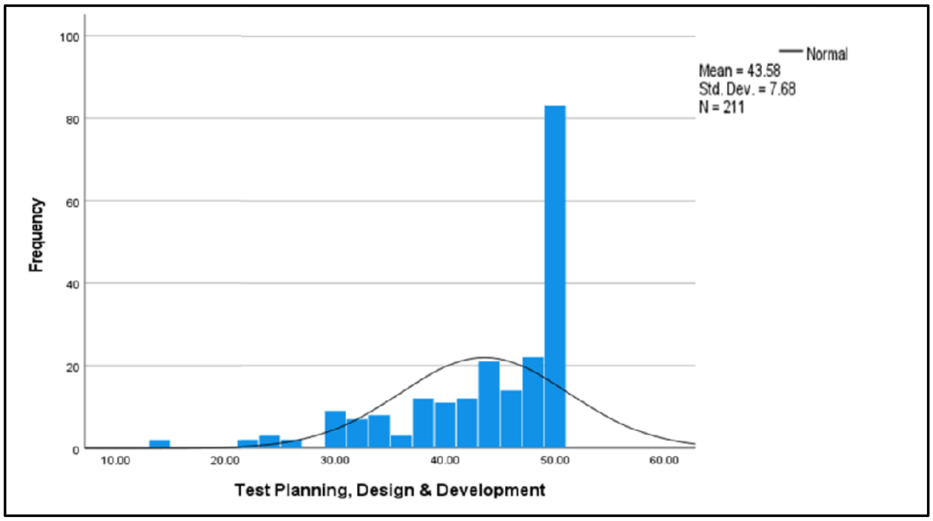

Figure 4.8: Histogram of the data in IV4 (Test Planning, Design and Development)

As in the Figure 4.8 the histogram is negatively skewed. The majority of the respondents have given the answers to the questions related to IV4 in a way that the total score is being 50.

IV5: Execution and Management of Tests

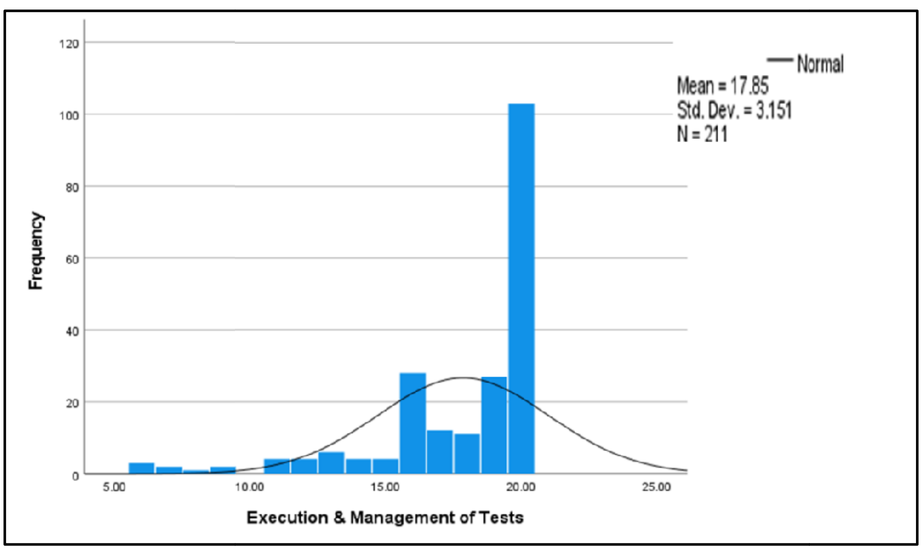

Figure 4.9: Histogram of the data in IV5 Execution and Management of Tests)

In Figure 4.9 also the histogram is negatively skewed which means that the majority of the respondents have given the answers for the questions related to IV5 in a way that the total rating is being 20.

IV6: Test Program Review and Assessment

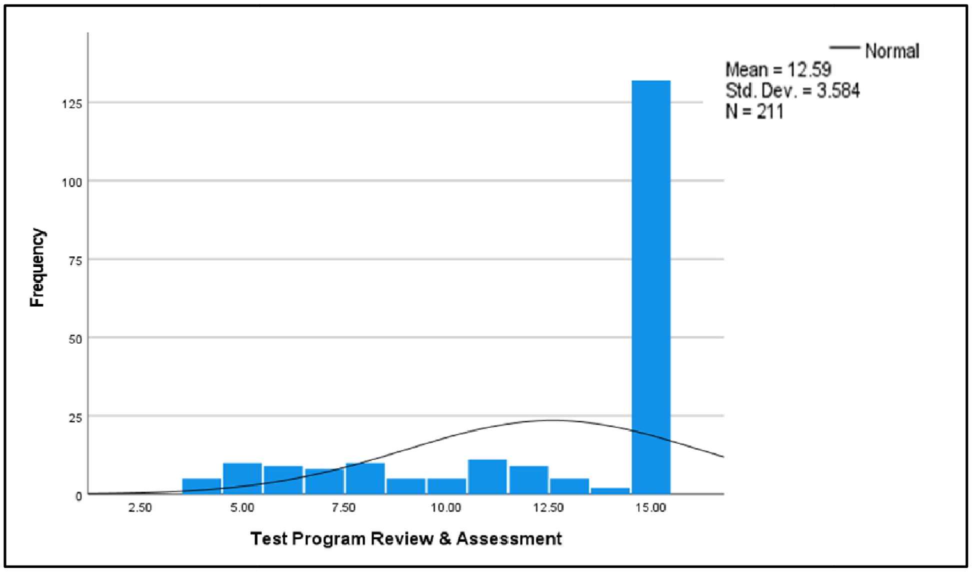

Figure 4.10: Histogram of the data in IV6 (Test Program Review and Assessment)

The histogram presented in Figure 4.10 is also negatively skewed. The Majority of the respondents have answered to the questions related to this IV in a way that the total rating is being 15.

DV: Success Level of Test Automation

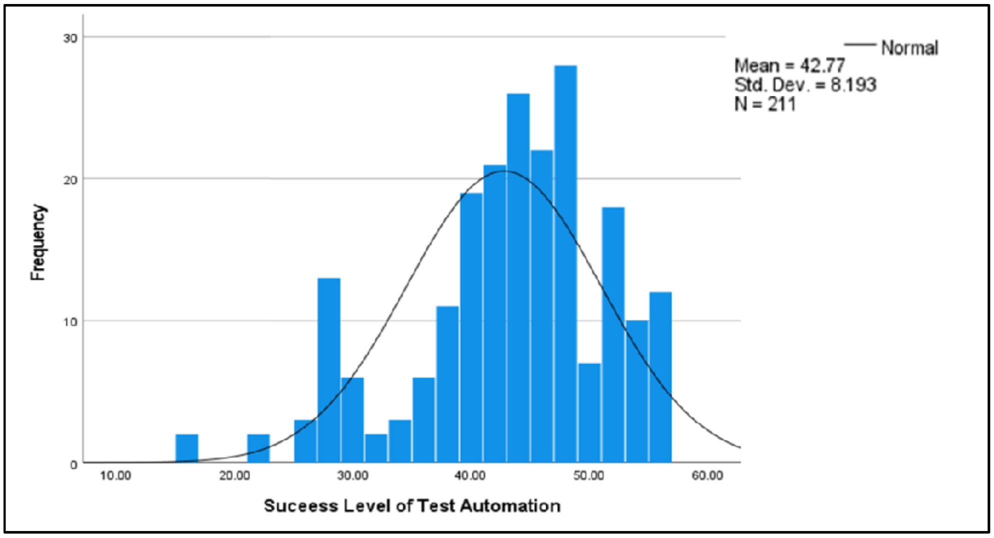

Figure 4.11: Histogram of the data in DV (Success Level of Test Automation)

Figure 4.11 shows a systematic histogram which means that the data collected for the questions related to the DV are normally distributed.

4.5 Reliability Analysis

In order to verify the internal consistency and the appropriateness of the questions used in the survey questionnaire, the reliability analysis was done using Cronbach's Alpha Reliability Analysis method.

Table 4.2: Cronbach's Alpha - Reliability Analysis of Survey Questionnaire

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.953	.956	47

As per the rule of thumb of this analysis method, if alpha value is more than 0.9, it is considered as internal consistency of the questions is excellent. As in Table 4.2 Chronbach's alpha value is 0.953 for a total of 47 questions which are used to gather data related to following ATLM in the test automation and the success level of test automation and therefore, the questionnaire can be considered as having an excellent internal reliability of the questions.

4.6 Inferential Analysis

After the Descriptive Analysis done for each IV and DV, an Inferential Analysis was conducted by measuring the statistical relationship between variables with the intention of generalizing the results obtained through the random probability sample to the population where the sample is derived. Further, the hypotheses which were built and discussed under Chapter 3 were tested through a correlation analysis. A regression analysis was conducted in order to build a model to represent the relationship between IVs and DV. 1% (0.01) level of significance was used throughout the analyses done within this study.

Even though the total number of respondents was 240, 29 of them have responded as they are not doing test automation at their companies. Therefore, the total number of respondents who claimed that they are doing test automation at their companies is 211 and therefore, the number of cases considered for the inferential analyses is 211.

4.6.1 Correlation Analysis

4.6.1.1 Linear Relationships between Variables

Before analyzing the correlation between each independent variable and dependent variable, it is vital to see whether each independent variable is having a linear relationship with the dependent variable.

.

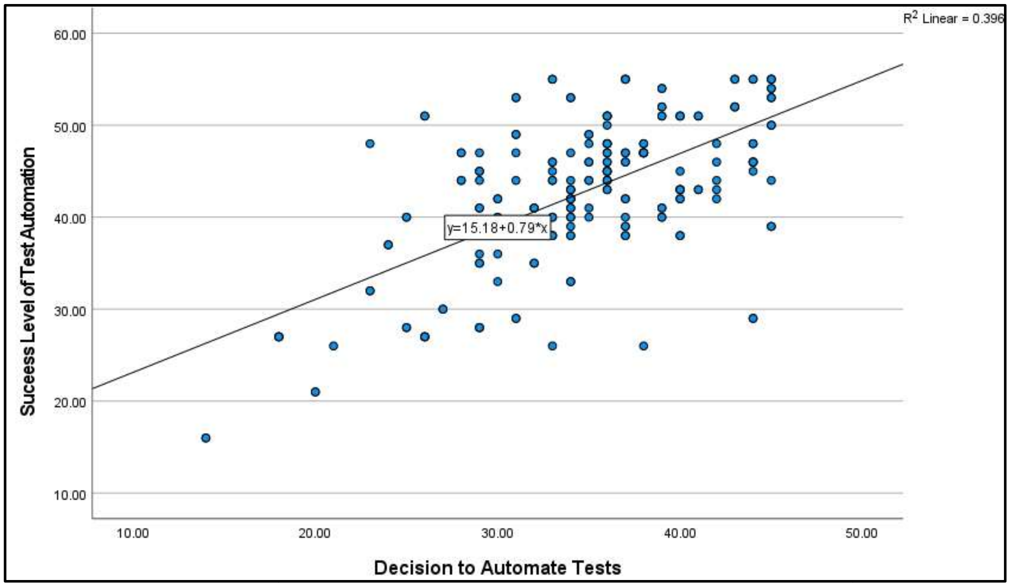

Figure 4.12: Scatter Plot for Decision to Automate Tests vs Success Level of Test Automation

As per the distribution of data in figure 4.12 there is a positive linear relationship between the Decision to Automate Tests and the Success Level of Test Automation.

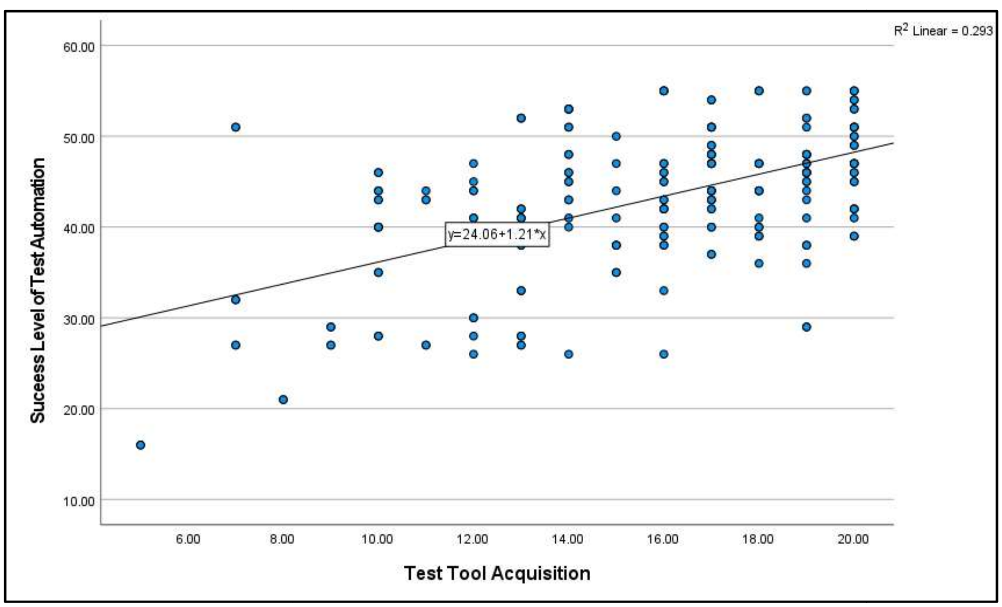

Figure 4.13: Scatter Plot for Test Tool Acquisition vs Success Level of Test Automation

Figure 4.13 shows that a positive linear relationship is there between Test Tool Acquisition and the Success Level of Test Automation.

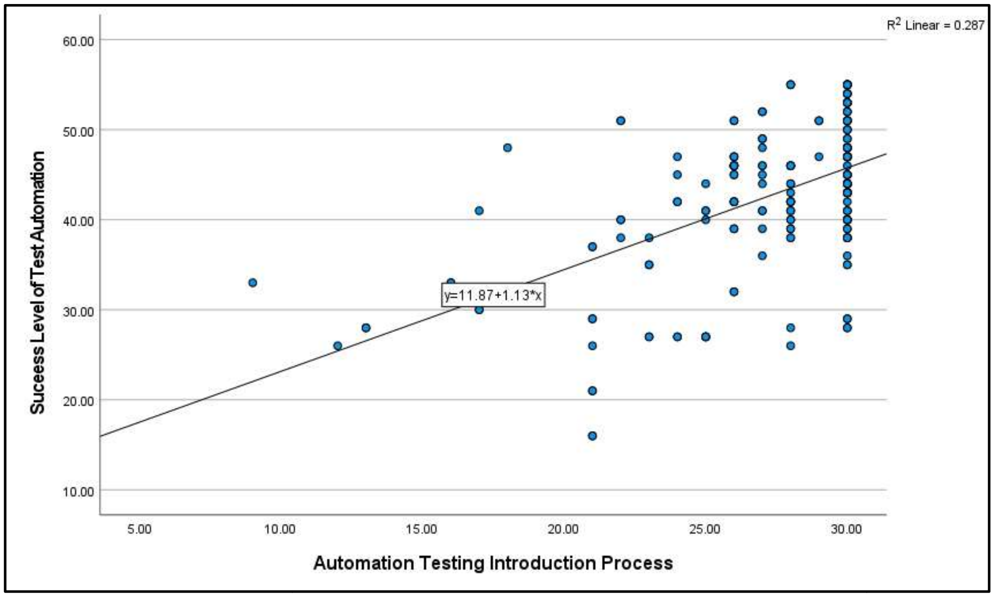

Figure 4.14: Scatter Plot for Automation Testing Introduction Process vs Success Level of Test Automation

The positive linear relationship between Automation Testing Introduction Process and the Success Level of Test Automation is depicted in Figure 4.14.

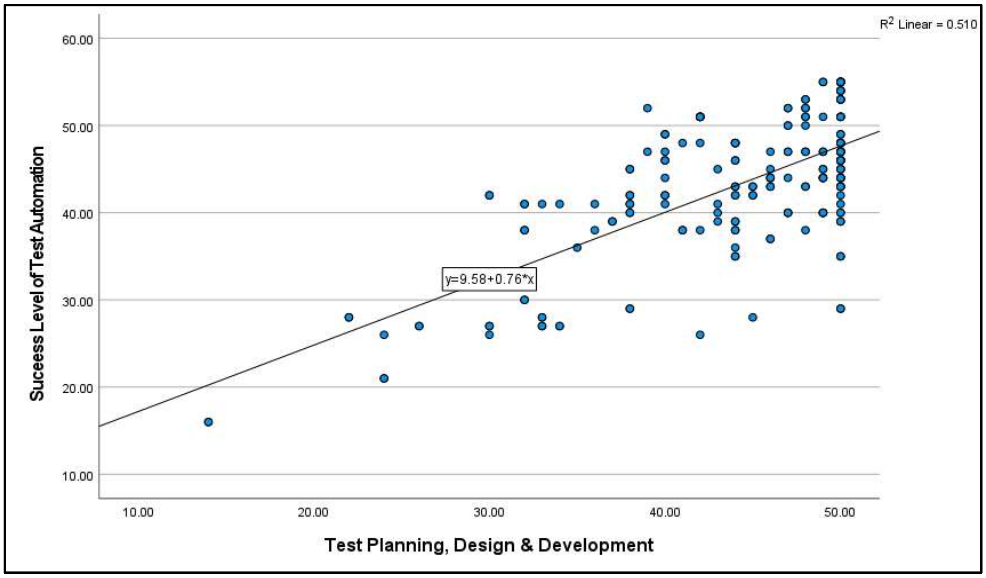

Figure 4.15: Scatter Plot for Test Planning, Design & Development vs Success Level of Test Automation

Figure 4.15 shows that a positive linear relationship is there between Test Planning, Design & Development and the Success Level of Test Automation.

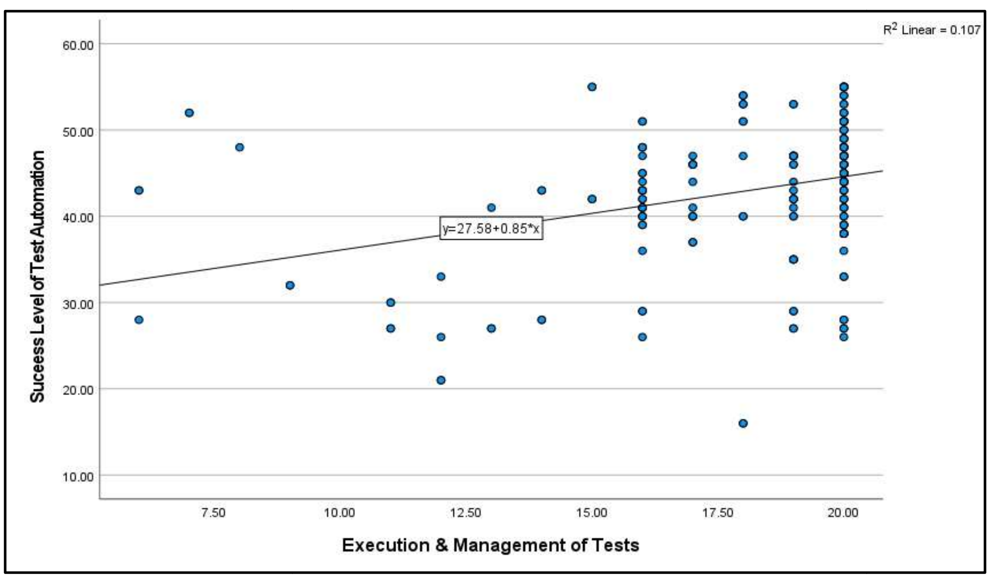

Figure 4.16: Execution & Management of Tests vs Success Level of Test Automation

As in Figure 4.16 Execution and Management of Tests and the Success Level of Test Automation has a linear relationship.

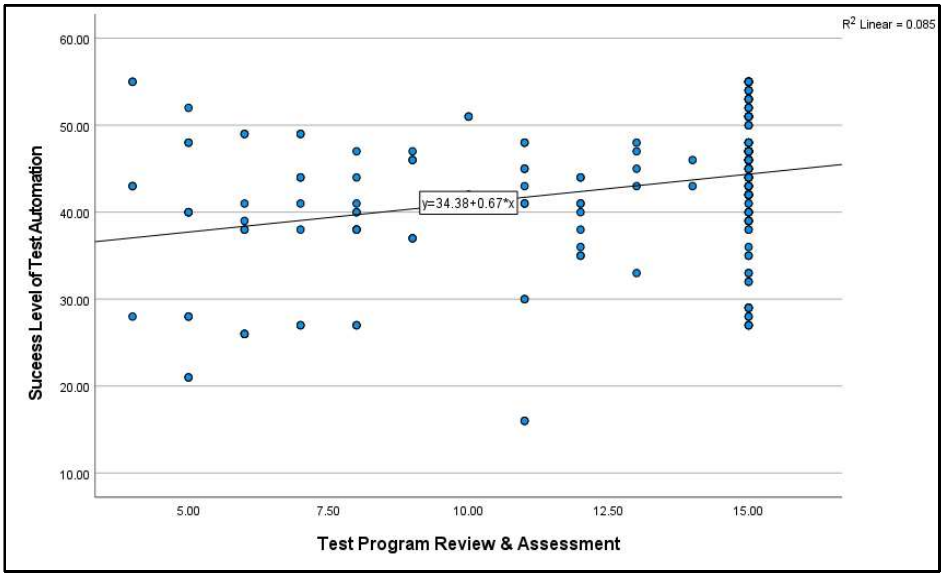

Figure 4.17: Test Program Review & Assessment of Tests vs Success Level of Test Automation

As per the Figure 4.17, there is a positive linear relationship between Test Program Review & Assessment and the Success Level of Test Automation.

4.6.1.2 Pearson Correlation

Since all the IVs and DV are derived as continuous variables, correlation between each IV and DV are calculated based on Pearson's Product-Moment Correlation.

Table 4.3: Correlations between Variables

Correlations								
		Decision to Automate Tests	Test Tool Acquisition	Automation Testing Introduction Process	Test Planning, Design & Development	Execution & Management of Tests	Test Program Review & Assessment	Success Level of Test Automation
Decision to Automate Tests	Pearson Correlation	1	.681**	.498**	.635**	.298**	.282**	.629**
	Sig. (2-tailed)		.000	.000	.000	.000	.000	.000
	N	211	211	211	211	211	211	211
Test Tool Acquisition	Pearson Correlation	.681**	1	.414**	.548**	.349**	.293**	.541**
	Sig. (2-tailed)	.000		.000	.000	.000	.000	.000

	N	211	211	211	211	211	211	211
Automation Testing Introduction Process	Pearson Correlation	.498**	.414**	1	.597**	.395**	.282**	.536**
	Sig. (2-tailed)	.000	.000		.000	.000	.000	.000
	N	211	211	211	211	211	211	211
Test Planning, Design & Development	Pearson Correlation	.635**	.548**	.597**	1	.282**	.272**	.714**
	Sig. (2-tailed)	.000	.000	.000		.000	.000	.000
	N	211	211	211	211	211	211	211
Execution & Management of Tests	Pearson Correlation	.298**	.349**	.395**	.282**	1	.335**	.327**
	Sig. (2-tailed)	.000	.000	.000	.000		.000	.000
	N	211	211	211	211	211	211	211
Test Program Review & Assessment	Pearson Correlation	.282**	.293**	.282**	.272**	.335**	1	.291**
	Sig. (2-tailed)	.000	.000	.000	.000	.000		.000
	N	211	211	211	211	211	211	211
Success Level of Test Automation	Pearson Correlation	.629**	.541**	.536**	.714**	.327**	.291**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	
	N	211	211	211	211	211	211	211

**. Correlation is significant at the 0.01 level (2-tailed).

As per the values in Table 4.3, Pearson correlation that each of the IV1, IV2, IV3 and IV4 are having with DV is between + 0.50 and + 1. Therefore, these 4 IVs, "Decision to Automate Tests", "Test Tool Acquisition", "Automation Testing Introduction Process" and "Test Planning, Design and Development" have a strong positive correlation with the Success of Test Automation.

Further, Pearson correlation that each IV5 and IV6 are having with DV are between + 0.30 and + 0.49. Therefore, "Execution and Management of Tests" and "Test Program Review and Assessment" have a medium positive correlation with the Success of Test Automation.

4.6.2 Hypothesis Testing

As it was discussed during the Chapter 3: Methodology, 6 main hypotheses were defined related to the 6 IVs discussed throughout this study. Those hypotheses were validated based on the correlation analysis discussed under the topic 4.6.1.2 Pearson Correlation.

Hypothesis 1 - Related to IV1 (Decision to Automate Tests)

$H1_a$ **-** Decision to automate tests has an impact on the success level of test automation.

$H1_0$ **-** Decision to automate tests does not have an impact on the success level of test automation.

Table 4.4: Correlation Analysis for the variable, Decision to Automate Tests

Correlations

		Decision to Automate Tests	Success Level of Test Automation
Decision to Automate Tests	Pearson Correlation	1	.629**
	Sig. (2-tailed)		.000
	N	211	211
Success Level of Test Automation	Pearson Correlation	.629**	1
	Sig. (2-tailed)	.000	
	N	211	211

**. Correlation is significant at the 0.01 level (2-tailed).

As in Table 4.4, the significance level between Decision to Automate Tests and the Success Level of Test Automation is 0.000 which is less than 0.01 and therefore, the null hypothesis can be rejected and the alternative hypothesis can be accepted. Therefore, it is concluded that the decision to automate tests has an impact on the success level of test automation.

Hypothesis 2 - Related to IV2 (Test Tool Acquisition)

$H2_a$ **-** Test tool acquisition has an impact on the success level of test automation.

$H2_0$ **-** Test tool acquisition does not have an impact on the success level of test automation.

Table 4.5: Correlation Analysis for the variable, Test Tool Acquisition

Correlations			
		Test Tool Acquisition	Success Level of Test Automation
Test Tool Acquisition	Pearson Correlation	1	.541**
	Sig. (2-tailed)		.000
	N	211	211
Success Level of Test Automation	Pearson Correlation	.541**	1
	Sig. (2-tailed)	.000	
	N	211	211
**. Correlation is significant at the 0.01 level (2-tailed).			

As in Table 4.5, the significance level between Test Tool Acquisition and the Success Level of Test Automation is 0.000 which is less than 0.01 and therefore, the null hypothesis can be rejected and the alternative hypothesis can be accepted. Therefore, this concludes that the test tool acquisition has an impact on the success level of test automation.

Hypothesis 3 - Related to IV3 (Automated Testing Introduction Process)

H3a - Automated testing introduction process has an impact on the success level of test automation.

H30 - Automated testing introduction process does not have an impact on the success level of test automation.

Table 4.6: Correlation Analysis for the variable, Automation Testing Introduction Process

Correlations			
		Automation Testing Introduction Process	Success Level of Test Automation
Automation Testing Introduction Process	Pearson Correlation	1	.536**
	Sig. (2-tailed)		.000

	N	211	211
Success Level of Test Automation	Pearson Correlation	.536**	1
	Sig. (2-tailed)	.000	
	N	211	211

**. Correlation is significant at the 0.01 level (2-tailed).

As in Table 4.6, the significance level between Automation Testing Introduction Process and the Success Level of Test Automation is 0.000 which is less than 0.01 and therefore, the null hypothesis can be rejected and the alternative hypothesis can be accepted. Therefore, this concludes that the automation testing introduction process has an impact on the success level of test automation.

Hypothesis 4 - Related to IV4 (Test Planning, Design & Development)

$H4_a$ **-** Test planning, design & development have an impact on the success level of test automation.

$H4_0$ **-** Test planning, design & development does not have an impact on the success level of test automation.

Table 4.7: Correlation Analysis for the variable, Test Planning, Design and Development

Correlations		Test Planning, Design & Development	Success Level of Test Automation
Test Planning, Design & Development	Pearson Correlation	1	.714**
	Sig. (2-tailed)		.000
	N	211	211
Success Level of Test Automation	Pearson Correlation	.714**	1
	Sig. (2-tailed)	.000	
	N	211	211

**. Correlation is significant at the 0.01 level (2-tailed).

As in Table 4.7, the significance level between Test Planning, Design and Development and the Success Level of Test Automation is 0.000 which is less than 0.01 and therefore, the null hypothesis can be rejected and the alternative hypothesis can be accepted. Therefore, this concludes that the process of Test Planning, Design and Development has an impact on the success level of test automation.

Hypothesis 5 - Related to IV5 (Execution & Management of Tests)

$H5_a$ **-** Execution & Management of tests have an impact on the success level of test automation.

$H5_0$ **-** Execution & Management of tests does not have an impact on the success level of test automation.

Table 4.8: Correlation Analysis for the variable, Execution and Management of Tests

Correlations		Execution & Management of Tests	Success Level of Test Automation
Execution & Management of Tests	Pearson Correlation	1	.327**
	Sig. (2-tailed)		.000
	N	211	211
Success Level of Test Automation	Pearson Correlation	.327**	1
	Sig. (2-tailed)	.000	
	N	211	211

**. Correlation is significant at the 0.01 level (2-tailed).

As in Table 4.8, the significance level between Execution and Management of Tests and the Success Level of Test Automation is 0.000 which is less than 0.01 and therefore, the null hypothesis can be rejected and the alternative hypothesis can be accepted. Therefore, this concludes that Execution and Management of Tests has an impact on the success level of test automation.

Hypothesis 6 - Related to IV6 (Test Program Review & Assessment)

$H6_a$ **-** Test program review and assessment have an impact on the success level of test automation.

$H6_0$ **-** Test program review and assessment does not have an impact on the success level of test automation.

Table 4.9: Correlation Analysis for the variable, Test Program Review and Assessment

Correlations		Test Program Review & Assessment	Success Level of Test Automation
Test Program Review & Assessment	Pearson Correlation	1	.291**
	Sig. (2-tailed)		.000
	N	211	211
Success Level of Test Automation	Pearson Correlation	.291**	1
	Sig. (2-tailed)	.000	
	N	211	211

**. Correlation is significant at the 0.01 level (2-tailed).

As in Table 4.9, the significance level between Test Program Review and Assessment and the Success Level of Test Automation is 0.000 which is less than 0.01 and therefore, the null hypothesis can be rejected and the alternative hypothesis can be accepted. Therefore, this concludes that Test Program Review and Assessment has an impact on the success level of test automation.

4.6.3 Regression Analysis with Multiple Linear Regression

The Multiple Linear Regression approach is used to model the relationship between the dependent variable and all the independent variables discussed earlier in this chapter.

4.6.3.1 Testing Assumptions of Multiple Linear Regression

Before moving to the Multiple Linear Regression analysis, it is a must to test the assumptions associated with this model. Those assumptions are "Normality" which means that the residuals are normally distributed, "Linearity" which means that there should be a linear relationship between each IV and DV, "Homoscedasticity" which denotes that the error terms variance are constant across the independent variables' values, and "Absence of Multicollinearity" which means that IVs are not highly correlated with each other. (Assumptions of Multiple Linear Regression - Statistics Solutions, 2021).

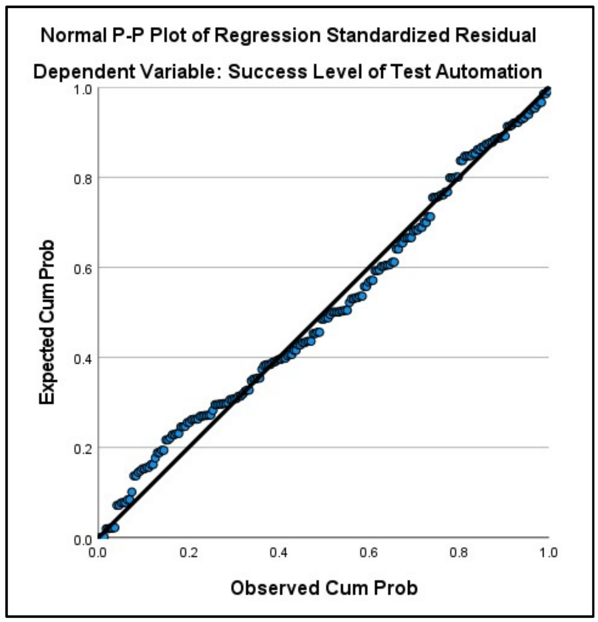

Figure 4.18: Normal P-P Plot of Regression Standardized Residual

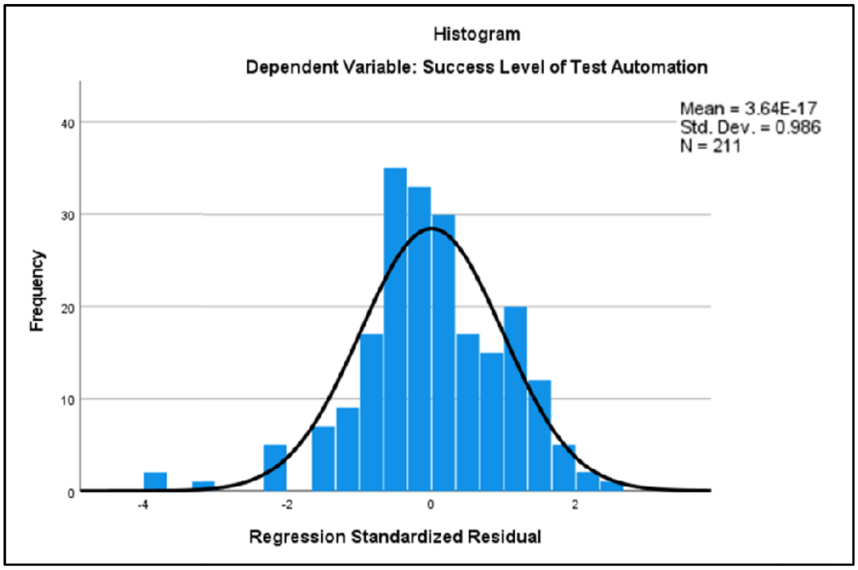

Figure 4.19: Histogram

Figure 4.18 and Figure 4.19 represents that the data is normally distributed and therefore, the first assumption, Normality is met.

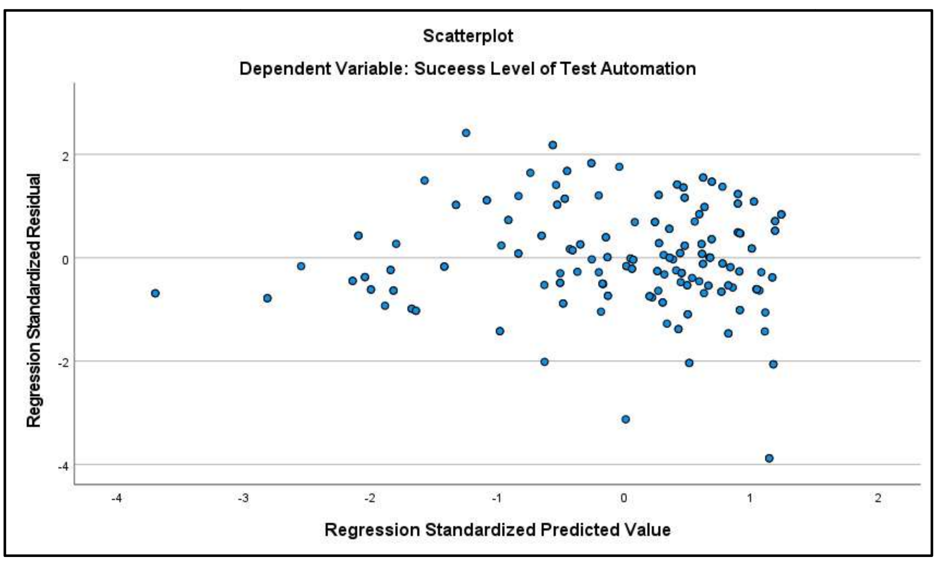

Figure 4.20: Scatter Plot of Residuals

In the scatter plot depicted in Figure 4.20, data points are equally distributed below and above the X axis and also the left side and right side of the Y axis. It indicates that the assumption, Homoscedasticity is met.

Table 4.10: Coefficients

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	.454	2.993		.152	.879		
	Decision to Automate Tests	.270	.088	.214	3.087	.002	.428	2.339
	Test Tool Acquisition	.172	.144	.077	1.189	.236	.493	2.030
	Automation Testing Introduction Process	.195	.126	.092	1.538	.126	.571	1.750
	Test Planning, Design & Development	.484	.070	.453	6.897	.000	.476	2.101
	Execution & Management of Tests	.153	.135	.059	1.133	.259	.763	1.311
	Test Program Review & Assessment	.090	.113	.040	.797	.426	.836	1.197

a. Dependent Variable: Success Level of Test Automation

As it is depicted in Table 4.10, Variance Inflation Factor (VIF) of each variable is less than 10. Therefore, it indicates the assumption, Absence of Multicollinearity is met.

The assumption of Linearity is already discussed together with scatter plots for each IV and DV under the topic 4.6.1.1 Linear Relationships between Variables.

Therefore, since all the assumptions are satisfied, Multiple Linear Regression analysis is done with the collected data sample and it is discussed under the topic 4.6.3.2 Multiple Linear Regression Analysis.

4.6.3.2 Multiple Linear Regression Analysis

The Multiple Linear Regression Analysis is done in order to build a model to represent the relationship that all the IVs are collectively having on the DV. Therefore, it can be interpreted as a model which represents the relationship between following the ATLM on the success level of test automation.

Table 4.11: Model Summary

Model Summary[b]

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.762[a]	.580	.568	5.38479	.580	47.018	6	204	.000

a. Predictors: (Constant), Test Program Review & Assessment, Test Planning, Design & Development, Execution & Management of Tests, Test Tool Acquisition, Automation Testing Introduction Process, Decision to Automate Tests

b. Dependent Variable: Success Level of Test Automation

The summary of multiple linear regression analysis for the DV and all the IVs is shown in Table 4.11. This represents the strength of the relationship between the IVs and the DV. The R-value, multiple correlation coefficient is 0.762 and it indicates that there is a strong linear correlation between the observed value of DV and the value of DV predicted in the model.

R-squared, the coefficient of determination is 0.580 which means that DV (Success Level of Test Automation) is influenced by 58.0% by all the IVs. It indicates that the regression model fits the observed data well and also it represents the model accuracy. This can be interpreted as Success Level of Test Automation is influenced by 58.0% by following ATLM in test automation.

Table 4.12: Analysis of Variance (ANOVA)

ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	8179.911	6	1363.319	47.018	.000[b]
	Residual	5915.169	204	28.996		
	Total	14095.081	210			

a. Dependent Variable: Suceess Level of Test Automation

b. Predictors: (Constant), Test Program Review & Assessment, Test Planning, Design & Development, Execution & Management of Tests, Test Tool Acquisition, Automation Testing Introduction Process, Decision to Automate Tests

As per the Table 4.12, probability level of significance is <0.001 which is much smaller than the 0.01, the level of significance considered in this study. Therefore, “Decision to Automate Tests”, “Test Tool Acquisition”, “Automation Testing Introduction Process”, “Test Planning, Design and Development”, “Execution and Management of Tests”, and “Test Program Review and Assessment” have a significant effect simultaneously on the Success Level of Test Automation. Therefore, this can be interpreted as following ATLM in test automation has a significant effect on the success level of test automation.

Table 4.13: Coefficients

Coefficients[a]						
		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	.454	2.993		.152	.879
	Decision to Automate Tests	.270	.088	.214	3.087	.002
	Test Tool Acquisition	.172	.144	.077	1.189	.236
	Automation Testing Introduction Process	.195	.126	.092	1.538	.126
	Test Planning, Design & Development	.484	.070	.453	6.897	.000
	Execution & Management of Tests	.153	.135	.059	1.133	.259
	Test Program Review & Assessment	.090	.113	.040	.797	.426

a. Dependent Variable: Success Level of Test Automation

Table 4.13 depicts that the coefficient values of "Decision to Automate Tests" and "Test Planning, Design and Development" are less than 0.01 and therefore, these two IVs are significant to the derived model. However, coefficient values of all other IVs are greater than 0.01 and therefore, they are not significant to the derived model.

5. CONCLUSION, RECOMMMENDATIONS AND FUTURE WORK

5.1 Conclusion

The main research question considered in this research study is to identify whether there is a relationship between following ATLM and the success level of test automation.

As per the statistical data analyses presented and discussed in the chapter 4, some of the steps in ATLM namely "Decision to Automate Tests", "Test Tool Acquisition", "Automation Testing Introduction Process" and "Test Planning, Design and Development" have a strong positive correlation with the Success of Test Automation. The correlation between other 2 steps of ATLM, "Execution and Management of Tests" and "Test Program Review and Assessment", have a medium positive correlation with the Success of Test Automation.

However, it is possible to conclude that, following ATLM has an impact on the success level of test automation in the IT industry is Sri Lanka.

5.1.1 Attaining Research Objectives

The statistical data analysis has revealed some facts which help to determine whether the research objectives are met. Following are the research objectives stated at the Chapter 1 and the details revealed related to those objectives are described below.

- **Identify whether the ATLM is followed by the IT organizations in Sri Lanka.**

There was a set of questions in the survey questionnaire focusing on the 6 steps in ATLM. 98% of the respondents have answered these questions favorable for following ATLM above average. Also 83.88% of the respondents have answered these questions favorable for ATLM over 75%. Further, 8.05% of the respondents have answered in a way that they are following ATLM 100%.

- **Assess the level of success in test automation in IT organizations in Sri Lanka.**

In addition to the questions related to the 6 steps in ATLM, another set of questions was there to assess the level of success in test automation. As per the survey data collected along with these questions, 96% of the respondents have answered these questions indicating an above average success level. Further, 66.8% of respondents have indicated that they are achieving more than 75% of success level in test automation.

- **Identify the correlation between ATLM and the level of success in test automation.**

As per the inferential statistics discussed in the Chapter 4, each step in ATLM is having a positive correlation with the level of success in test automation. Out of the 6 steps in ATLM, "Decision to Automate Tests", "Test Tool Acquisition", "Automation Testing Introduction Process" and "Test Planning, Design and Development" are having a strong positive correlation while "Execution and Management of Tests" and "Test Program Review and Assessment" are having a medium positive correlation with the success level of test automation.

- **Identify the key factors affecting on the success of test automation in IT organizations in Sri Lanka.**

As it is mentioned above, "Decision to Automate Tests", "Test Tool Acquisition", "Automation Testing Introduction Process" and "Test Planning, Design and Development" are the key contributors for the success of test automation in the IT industry in Sri Lanka.

5.2 Recommendations

As discussed above, "Test Planning, Design and Development" has the highest correlation with the success of test automation. Therefore, it is important to pay attention to the tasks related to this stage as this is the most critical contributor for the success of test automation. Organizations need to plan the test automation initiatives carefully considering the factors such as test data, hardware, software, network, roles and responsibilities, risks and contingencies. Further, number of test cases, defining test procedures, test design standards etc. also should be considered at the test designing. Importantly, the attention should be paid to the reusability, maintainability, repeatability as well as test development standards when developing the automation tests.

Since "Decision to Automate Tests" also has a positive correlation with automation success, it is worth getting the management support by convincing the management by highlighting the benefits of automation as well as by overcoming their false expectations. "Test Tool Acquisition" is another stage which has a positive correlation with the success of test automation. Therefore, it is important to evaluate the tools/technologies with a set of evaluation criteria for finalizing the tool and it will help to get the management support for acquiring the tool. In addition to that, "Automation Testing Introduction Process" is also contributing highly for the success of test automation. Having an overall test process and a strategy is crucial for a company as it is needed for test automation also. Analyzing the test process & strategy, test requirements and team skills and mapping the test tool testing requirements needs to be done properly.

However, even though the above 4 stages are the most important contributors for the test automation success, the other 2 stages, "Execution and Management of Tests" and "Test Program Review and Assessment" also have a positive impact on the automation success. Therefore, it will be worthwhile to pay attention to the way of executing tests, coverage of testing and reporting test results under the execution stage while considering how to evaluate the overall test automation process in order to assess the effectiveness, track the lessons learned and come up with ideas to improve the process in future.

5.3 Limitations of the Study

Even though this research study has revealed some key factors related to the ATLM and the success of test automation, it also has some limitations.

This study was planned to be done with a minimum 374 respondents in order to achieve a 95% confidence level and a 5% margin of error. However, only 240 responses were received resulting in a confidence level over 85%. The results could have been more accurate if the expected number of responses were received.

Further, even though the data collection is done with Voluntary Response Sampling technique, 37% of respondents are with less than 3 years of experience in the QA and therefore, it could lead to a bias in the results.

The questionnaire is mainly focusing on identifying whether a company is following ATLM and also the level of success of test automation. Therefore, the questions are targeting to gather some data specific to a particular company and their processes. There is a possibility that the respondents might be reluctant to give their honest opinion concerning their company reputation and the confidentiality which also lead to a bias in the results of this study.

5.4 Future Work

Still there is a research gap in the research area of Software Test Automation in the IT industry in Sri Lanka.

As per the analyses done in this study, 12% of QA professionals in Sri Lanka are not doing test automation at their companies even though it gives a lot of benefits over manual testing. It is worthwhile to identify the reasons for not following the test automation.

Test automation could be done with different tools and technologies and it can have an impact on the success of test automation. Therefore, there is a research gap to identify the types or characteristics of the tools and technologies in order to achieve greater success in test automation.

Current research study was done by analyzing the data collected from QA professionals in different levels including QA Managers, Senior QA Engineers, QA Engineers, Associate QA Engineers and Interns, with different years of experience. Therefore, it will be worthwhile to take the job category and the years of experience also into account when analyzing their responses in future studies in the same research area.

Further, the approach of following ATLM and the success of test automation could be varying based on the technical domain of the software under test because the technologies used for the application development, complexity of the logical flows of application development, level of testing requirements and several other factors are not being same in all the applications. Therefore, conducting a study similar to this current research study considering the technical domain of the software under test may give more accurate results on the same research problem.

REFERENCES

Adler, J., & Parmryd, I. (2010). Quantifying localization by correlation: The pearson correlation coefficient is superior to the Mander's overlap coefficient. *Cytometry Part A*. https://doi.org/10.1002/cyto.a.20896

Alegroth, E., Feldt, R., & Olsson, H. H. (2013). Transitioning Manual System Test Suites to Automated Testing: An Industrial Case Study. *2013 IEEE Sixth International Conference on Software Testing, Verification and Validation*, 56-65. doi:10.1109/icst.2013.14

Amannejad, Y., Garousi, V., Irving, R. & Sahaf, Z. A Search-Based Approach for Cost-Effective Software Test Automation Decision Support and an Industrial Case Study. *Software Testing, Verification and Validation Workshops (ICSTW), 2014 IEEE Seventh International Conference on* 302–311 (2014).doi:10.1109/ICSTW.2014.34

Asiamah, N., Mensah, H. K., & Oteng-Abayie, E. F. (2017). General, target, and accessible population: Demystifying the concepts for effective sampling. *Qualitative Report*, *22*(6), 1607–1621

Bevans, R. (2020, January 8). *Statistical tests: which one should you use?* Https://Www.Scribbr.Com/. https://www.scribbr.com/statistics/statistical-tests/

Clark, V. (1991). Sample size determination. *Plastic and Reconstructive Surgery*, *87*(3), 569–573. https://doi.org/10.1097/00006534-199103000-00030

Davis, R. B., & Mukamal, K. J. (2006). Hypothesis testing: Means. *Circulation*, *114*(10), 1078–1082. https://doi.org/10.1161/CIRCULATIONAHA.105.586461

Dickson, A., Adu-Agyem, J., & Emad Kamil, H. (2018). Theoretical and conceptual framework: mandatory ingredients of a quality research. *International Journal of*

Scientific Research, *7*(1), 438–441.

Dubey, S., Takwane, S. & Dighe, D.(2017). Study in Various Phases of Software Testing Life Cycle. *7th International Conference on Recent Trends in Engineering, Science & Management*,1435-1443

Dustin, E., Rashka, J., & Paul, J. (1999). *Automated software testing introduction, management, and performance*. Reading, Mass.: Addison-Wesley.

Eldh, S., Andersson, K., Ermedahl, A. & Wiklund, K. "Towards a Test Automation Improvement Model (TAIM)", *Software Testing Verification and Validation Workshops (ICSTW) 2014 IEEE Seventh International Conference on*, pp. 337-342, 2014.

Eriksson U. (2016, May 19). The A to Z Guide to the Software Testing Process [Web log post]. Retrieved April 10, 2019, from https://reqtest.com/testing-blog/the-a-to-z-guide-to-the-software-testing-process/pettichord, B. (2001).http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.471.9363&rep=rep1&type=pdf. STAR West, San Jose.

Flannelly, L. T., Flannelly, K. J., & Jankowski, K. R. B. (2014). Independent, Dependent, and Other Variables in Healthcare and Chaplaincy Research. *Journal of Health Care Chaplaincy*, *20*(4), 161–170. https://doi.org/10.1080/08854726.2014.959374

Garousi, V., & Elberzhager, F. (2017). Test Automation: Not Just for Test Execution. *IEEE Software*,*34*(2), 90-96. doi:10.1109/ms.2017.34

Humpage, S. (2000). An introduction to regression analysis. *Sensors (Peterborough, NH)*, *17*(9), 68–74. https://doi.org/10.1002/9781118267912.ch6

Hushalini, S., Randunu, R. P. A. A., Maddumahewa, R. M. & Manawadu C. D. (2014). Software Test Automation in Practice: Empirical Study from Sri Lanka. *COMPUSOFT, An international journal of advanced computer technology, 3* (11), 1232-1237

Hooda, I., & Chhillar, R. S. (2015). Software Test Process, Testing Types and Techniques. *International Journal of Computer Applications, 111*(13), 10-14. doi:10.5120/19597-1433

Jayachandran, N., 2005. Understanding ROI Metrics for Software Test Automation. *Graduate Theses and Dissertations*

Kasurinen J., Taipale, O. and Smolander, K. (2010). Software Test Automation in Practice: Empirical Observations.*Hindawi Publishing Corporation, 2010.* doi:10.1155/2010/620836

Kumar, D., & Mishra, K. (2016). The Impacts of Test Automation on Softwares Cost, Quality and Time to Market. *Procedia Computer Science, 79*, 8-15. doi:10.1016/j.procs.2016.03.003

Leotta, M., Clerissi, D., Ricca, F., & Tonella, P. (2013). Capture-replay vs. programmable web testing: An empirical assessment during test case evolution. *2013 20th Working Conference on Reverse Engineering (WCRE)*. doi:10.1109/wcre.2013.6671302

Merrill, P., 2020. *13 Questions That Determine Test Automation Success | Techbeacon*. [online] TechBeacon. Available at: <https://techbeacon.com/app-dev-testing/13-questions-determine-test-automation-success> [Accessed 28 October 2020].

Muthusundar, S. K., Thara, D., & Titus, T. A., (2011). Comparative Study of Test Automation ROI. *Indian Journal of Computer Science & Engineering (IJCSE), 2(4),* 615-623

Myers, G. J., Sandler, C. & Badgett, T. *The art of software testing*. (John Wiley & Sons: 2011)

Persson, C. and Yilmazturk, N. "Establishment of automated regression testing at ABB: industrial experience report on 'avoiding the pitfalls'," *Proceedings. 19th International Conference on Automated Software Engineering, 2004.*, Linz, Austria, 2004, pp. 112-121, doi: 10.1109/ASE.2004.1342729.

Pierre Audoin Consultants (PAC), "Software testing spends to hit Euro 100bn by 2014," *https://www.pac-online.com/software-testing-spends-hit-eur100bn-2014-press-release,* 2014.

Pocatilu, P. "Automated Software Testing Process", Economy Informatics, no. 1, p. 97-99, 2002

Qualtrics. 2020. *How To Determine Sample Size In Research | Qualtrics*. [online] Available at: <https://www.qualtrics.com/uk/experience-management/research/determine-sample-size/?rid=ip&prevsite=en&newsite=uk&geo=NL&geomatch=uk> [Accessed 18 November 2020].

Rafi, D. M., Moses, K. R., Petersen, K., & Mantyla, M. V. (2012). Benefits and limitations of automated software testing: Systematic literature review and practitioner survey. *2012 7th International Workshop on Automation of Software Test (AST)*. doi:10.1109/iwast.2012.6228988

Rodrigues, A. and Dias-Neto, A., 2016. Relevance and Impact of Critical Factors of Success in Software Test Automation lifecycle. *Proceedings of the 1st Brazilian Symposium on Systematic and Automated Software Testing - SAST*,.

Saglietti, F. and Pinte, F. “Automated unit and integration testing for component-based software systems,” in *Proceedings of the International Workshop on Security and Dependability for Resource Constrained Embedded Systems (D4RCES’10)*, 2010, pp. 5:1–5:6.

Saher, N., Khan, D. M., Shahzad, F. & Karim, A.(2015). The Quality Assessment of Software Testing Procedure and Its Effects. *Sci.Int.(Lahore) , 27*(5),4865-4874

Sarstedt, M. & Mooi, E. (2014). A Concise Guide to Market Research - Chapter 7 Regression Analysis. In *Springer Texts in Business and Economics*. https://doi.org/10.1007/978-3-642-53965-7

Scherbaum, C. and Shockley, K., 2015. *Methods for analysing quantitative data for Business and anagement Students*. Sage Pubns Ltd.

SLASSCOM. (2020). SLASSCOM. Retrieved November 22, 2020, from https://slasscom.lk/srilanka-advantage

Sounders, M., Lewis, P. and Thornhill, A., 2021. *Research Methods for Business Students*. 6th ed. Harlow: Pearson Education Limited.

Statistics Solutions. 2021. *Assumptions Of Multiple Linear Regression - Statistics Solutions*. [online] Available at: <https://www.statisticssolutions.com/assumptions-of-multiple-linear-regression/#:~:text=Multivariate%20Normality%E2%80%93Multiple%20regression%20assumes,Inflation%20Factor%20(VIF)%20values.> [Accessed 16 January 2021].

Taber, K. S. (2018). The Use of Cronbach's Alpha When Developing and Reporting Research Instruments in Science Education. *Research in Science Education*, *48*(6), 1273–1296. https://doi.org/10.1007/s11165-016-9602-2

Taherdoost, H., 2016. Sampling Methods in Research Methodology; How to Choose a Sampling Technique for Research. *International Journal of Academic Research in Management (IJARM)*

Tavakol, M. and Dennick, R., 2011. Making sense of Cronbach's alpha. *Int J Med Educ*, [online] 2, pp.53-55. Available at: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4205511/#:~:text=Numerical%20values%20of%20alpha&text=There%20are%20different%20reports%20about,ranging%20from%200.70%20to%200.95.&text=A%20low%20value%20of%20alpha,between%20items%20or%20heterogeneous%20constructs.> [Accessed 29 December 2020].

Thummalapenta, S., Sinha, S., Singhania, N. and Chandra, S. "Automating test Automation," presented at the Proceedings of the 34th International Conference on Software Engineering, Zurich, Switzerland, 2012

Uriel, E., 2013. *Hypothesis testing in the multiple regression model*. Universidad de Valencia.

Wiklund, K., Eldh, S., Sundmark, D., & Lundqvist, K. (2017). Impediments for software test automation: A systematic literature review. *Software Testing, Verification and Reliability*, *27*(8). doi:10.1002/stvr.1639

"Why Test Automation: Automated Testing Benefits," [ONLINE] Available at: http://www.ranorex.com/why-test-automation.html. [Accessed 15 August 2020]

APPENDIX A: SURVEY QUESSIONAIRE

The Impact of Following the Automated Testing Life Cycle Methodology (ATLM) on the Success of Functional Test Automation - An Overview of the Sri Lankan Software Industry

I am Manori Wijesooriya, a postgraduate student of CSE Department, University of Moratuwa. As a partial fulfillment of the MBA in IT degree program, I am conducting a research study on;

"The Impact of Following Automated Testing Life Cycle Methodology (ATLM) on the Success of Functional Test Automation - A*n Overview of the Sri Lankan Software Industry"*

I would appreciate if you, as a Software Quality Assurance professional could spare about 10 minutes of your valuable time to fill and submit this questionnaire. Your complete response will be very important and helpful for me to conduct my research study.

All the details you will be providing will remain confidential and anonymous and will be used only for this academic purpose.

Thank you for spending your valuable time on this to help out me in my educational endeavors. I understand the value of your time and appreciate your commitment in submitting this survey questionnaire. Please do not hesitate to contact me if you have any concerns regarding this.

Thank You,

D. P. M. M. Wijesooriya | manori.18@cse.mrt.ac.lk
MBA in IT (2018)
Department of CSE
University of Moratuwa
Sri Lanka.

*Required

Section 1: Demographic Information

1. Years of experience you have in software QA *

   - ○ Less than 3 years
   - ○ 3 to 5 years
   - ○ 5 to 10 years
   - ○ More than 10 years

2. Job Category *

   - ○ Associate QA Engineer/Intern
   - ○ Senior/QA Engineer
   - ○ Senior/Automation Engineer
   - ○ QA Lead/Manager

3. Does your company use functional test automation in any of the projects? *

   - ○ Yes
   - ○ No

4. What are the things that QA/automation team will do when deciding to automate the testing in a particular project? *

	Never	Rarely	Sometimes	Often	Always
Takes the initiative and influence the management to use automation in projects					
Gets the clear understanding about the capabilities of the automation tool/framework					
Gets the clear understanding about the required level of technical expertise					

Prepare a project proposal for the test automation project					

5. In the cost-benefit analysis being done before starting the test automation in a project; *

	Never	Rarely	Sometimes	Often	Always
Quantitative benefits(eg: reduction in cost & schedule etc) are assessed					
Qualitative benefits(eg: system reliability and confidence level etc) are assessed					
Cost factors(eg: cost for the tool purchasing, training costs, initial schedule increase etc) are considered					

6. What are things being communicated to the top management in order to get their support for the test automation; *

	Never	Rarely	Sometimes	Often	Always
Required skills/capabilities of the testing team and the training requirements					
Costs incurred such as initial tool purchasing, schedule increase and training costs					

Section 2: Decision to Automate Tests

7. When selecting a test tool/framework; *

	Never	Rarely	Sometimes	Often	Always
Both Commercial & Free tools are considered					
A set of evaluation criteria is used to evaluate the tools					
Different capabilities of automation tool/framework are considered					
Issues/limitations of automation tool/framework are considered					

Section 3: Automation Testing Introduction Process

8. Regarding the test process of the company; *

	Never	Rarely	Sometimes	Often	Always
A standard process/procedure is followed in the manual testing					
The test process is documented and communicated to the test team					
The test process of the company is being considered when applying test automation into projects					

9. When choosing a test automation tool for a particular project; *

	Never	Rarely	Sometimes	Often	Always
Investigate whether an existing tool could be used for the new project					
Consider the testing requirements of the project					
Consider the test tool compatibility with the testing environment					

Section 4: Test Planning, Design & Development

10. What are the factors considered when planning to automate tests after finalizing a tool/framework? *

	Never	Rarely	Sometimes	Often	Always
Hardware, software and infrastructure					
Test data					
Test schedule					
Roles & responsibilities for team members					
Risks & contingencies					

11. What are the factors considered when designing & developing test cases for automation? *

	Never	Rarely	Sometimes	Often	Always
Thoroughness of the scope to be automated					
Logical grouping of test cases(eg: grouping test cases based on the modules in the system, consider the order of test execution etc)					
Reusability - extending some existing test cases					
Repeatability - executing the same tests repeatedly					
Maintainability					

Section 5: Execution & Management of Tests

12. When Executing the automated test cases; *

	Never	Rarely	Sometimes	Often	Always
Automation is executed within the planned timeline of overall test execution					
Automated test cases can be executed in different levels such as unit, integration, system and user acceptance					

tests					
Failed test cases are manually verified (to confirm whether they are valid bugs)					
A report with test results will be created by the automation tool itself or manually					

Section 6: Test Program Review and Assessment

13. After the test cases are implemented and executed; *

	Never	Rarely	Sometimes	Often	Always
Effectiveness of test automation is assessed and Return on Investment(ROI) is evaluated					
Performance of the test automation process is evaluated (considering the time taken to automate the given test scope)					
Lessons learned activities are tracked and considered for improvements in the future					

Section 7: Test Automation Success Evaluation

14. Select the correct answer regarding the test automation implementation and execution *

	Never	Rarely	Sometimes	Often	Always
Automation is well planned considering goals, Return on Investment (ROI) and resource requirements					
A feasibility analysis is done before applying test automation into a project (considering technical & economical feasibility)					
Dedicated & skilled people are available for test automation					
Test tool/test environment is available when needed					
Resources(hardware & personnel) are available to work on multiple automation projects simultaneously					

15. In automation scripting;

	Never	Rarely	Sometimes	Often	Always
Software development best practices are used					
Test scripts are re-used for similar test requirements					
Automated test cases are developed before, or in parallel with, application					

development					

16. When executing the automated tests;

	Never	Rarely	Sometimes	Often	Always
Automated tests are executed in multiple environments					
Automation is setup to be executed automatically on a defined frequency (eg: daily)					
Test results are same when executing the same tests multiple times					

Section 8: This section is appearing if the answer for the Question 3 is given as "No".

4. Have you attempted to apply functional test automation in any of the projects in your organization? *

- ○ We have never attempted to automate testing
- ○ We have done automation in the past. But it is not continued

5. As you think, what is the most relevant reason for not having/not continuing test automation in your organization? *

- ○ No-one (QA team or Management) initiated or raised a requirement to automate testing
- ○ We don't have technical expertise
- ○ We don't have Management Support

- ○ Automation takes more time/cost than manual testing

6. What is your opinion regarding applying test automation into the projects in your organization? *

- ○ Automation will be beneficial
- ○ Automation will introduce additional costs than its benefits
- ○ Automation will be an additional burden to the QA team

APPENDIX B: SUMMARY OF SURVEY RESULTS

Question Number	Question	Answers – Percentage of Respondents
1	Years of experience you have in software QA *	Less than 3 years – 37.1% 3 to 5 years – 31.7% 5 to 10 years – 22.9% More than 10 years – 8.3%
2	Job Category	Associate QA Engineer/Intern – 10.5% Senior/QA Engineer – 62.1% Senior/Automation Engineer – 9.2% QA Lead/Manager – 18.3%
3	Does your company use functional test automation in any of the projects?	Yes – 94.5% No – 5.5%